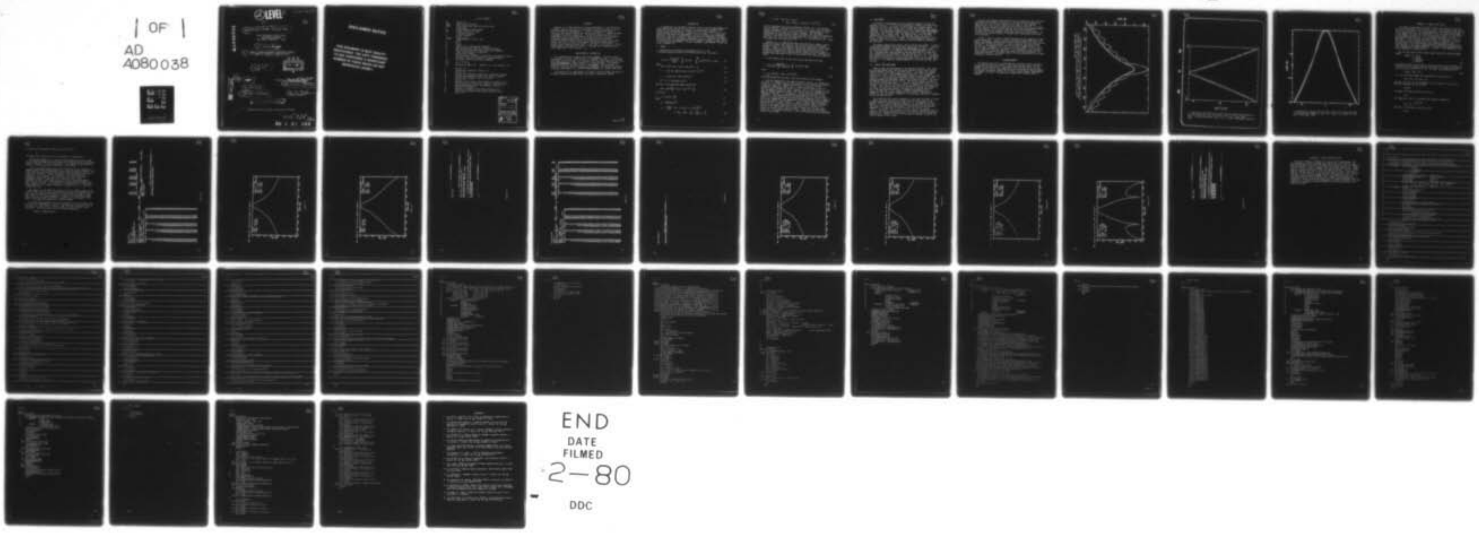
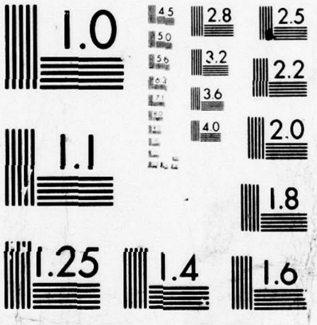
AD-A080 038   NAVAL UNDERWATER SYSTEMS CENTER NEW LONDON CT NEW LO--ETC F/G 17/1
CONVOL: A COMPUTER PROGRAM FOR PARAMETRIC SOURCE NEARFIELD AND --ETC(U)
JUL 79 M B MOFFETT, R H MELLEN

UNCLASSIFIED   NUSC-TM-791132   NL

1 OF 1
AD
A080038



END
DATE
FILMED
2-80
DDC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

2 LEVEL II

Code-72251

TM No.
791132

SC

ADA080038

14 NUSC-TM-791132

NAVAL UNDERWATER SYSTEMS CENTER
NEW LONDON LABORATORY
NEW LONDON, CONNECTICUT 06320

9 Technical Memo~~randum~~

6 CONVOL: A COMPUTER PROGRAM FOR PARAMETRIC SOURCE NEARFIELD AND FARFIELD BEAM PATTERNS.

DDC
RECEIVED
FEB 1 1980
B

12 47

11 Date: 17 Jul[redacted]79

Prepared by: Mark B. Moffett
Mark B. Moffett

10 Robert. H. /Mellen

R H Mellen
Robert H. Mellen

16 F33341

17 SF33341491

DDC FILE COPY

THIS DOCUMENT IS BEST QUALITY PRACTICABLE.
THE COPY FURNISHED TO DDC CONTAINED A
SIGNIFICANT NUMBER OF PAGES WHICH DO NOT
REPRODUCE LEGIBLY.

62633N

Approved for public release; distribution unlimited.

405918 gm

80 1 31 080

DISCLAIMER NOTICE

THIS DOCUMENT IS BEST QUALITY PRACTICABLE. THE COPY FURNISHED TO DDC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

LIST OF SYMBOLS

B^2	See Eq. (5)
BDG	bearing deviation gain
BDGAP	aperture-corrected bearing deviation gain
c	sound speed
D_0	primary-pressure beam pattern
DI_0	primary directivity index
f	difference frequency
f_0	primary frequency
I	see Eq. (3)
ISHAPE	shape parameter, see Eq. (A1)
j	$(-1)^{\frac{1}{2}}$
k	$2\pi f/c$
k_0	$2\pi f_0/c$
N	aspect ratio of rectangular projector
P	peak pressure amplitude of difference frequency
P_0	peak face pressure amplitude, one primary component
r	range (from projector to observer)
r'	source point distance
R_0	Rayleigh length, projector area/primary wavelength for piston projectors, projector length/π for endfire projector
SL_0	rms source level of one primary component
SL_0^*	$SL_0 + 20 \log f_0$
SL_1^*	$20 \log(\rho c^3/2\pi\sqrt{2}\beta) + 60$ dB//1μPa - m - kHz (see Ref. 14)
U	see Eq. (6)
y	variable of integration, see Eq. (3)
z	see Eq. (4)
α	primary wave absorption coefficient (nepers/unit length)
$\overline{\alpha}$	primary wave absorption coefficient (dB/unit length)
β	nonlinearity parameter (≈ 3.5 for water)
η	see Eq. (9)
θ	observer's polar angle (with respect to projector axis)
θ'	source-point polar angle (with respect to projector axis)
ν	angle between source point and observer, see Eq. (2)
ρ	ambient fluid density
ϕ	observer's azimuthal angle (about projector axis)
ϕ'	source point azimuthal angle (about projector axis)
χ	see Eq. (8)

ACCESSION for
NTIS White Section ☑
DDC Buff Section □
UNANNOUNCED □
JUSTIFICATION ____________

BY ____________
DISTRIBUTION/AVAILABILITY CODES
Dist. AVAIL. and/or SPECIAL
A | 23

ABSTRACT

Because it is often impractical to make measurements in the farfield of parametric acoustic sources, it is desirable to be able to predict the far field from nearfield measurements. A nearfield beam pattern theory, previously outlined [J. Acoust. Soc. Am. 63, 1622-1624 (L) (1978)], has been programmed for digital computation. The results compare favorably with experimental data from an absorption-limited source involving substantial difference-frequency generation in the primary farfield and from a saturation-limited source with most of the generation taking place in the primary nearfield. In the first example, the nearfield beam pattern is broader and the apparent source level is lower than in the farfield. In the second example, the nearfield pattern is narrower and the apparent source level higher than in the farfield.

ADMINISTRATIVE INFORMATION

This memorandum was prepared under project A70921, " Nonlinear Sensor Development," Principal Investigator, R.L. Schmidt (Code 3631). The Guidance and Control Block Principal is C. Ackerman (ARL/PSU), Navy subproject and task number SF 33-341-491, Project Manager, E. Liszka (SEA 034). The research described herein was performed under Project A61400, "Nearfield Model for Parametric Acoustic Sources," Principal Investigator, M.B. Moffett (Code 313); Associate Investigator, R.H. Mellen; Program Manager, J.H. Probus (MAT 08T1).

The authors of this memorandum are located at the New London Laboratory of the Naval Underwater Systems Center, New London, Connecticut, 06320.

INTRODUCTION

In experiments with parametric acoustic sources, farfield measurements are often impractical, because the farfield (the region where secondary signal generation has ceased) may be as remote as $5/\alpha$ from the projector[1] (α = primary absorption coefficient in nepers per unit length). To allow farfield prediction from nearfield measurements, a nearfield theory must be employed. Reference 2 describes a nearfield model and outlines a computation procedure. We can now report on the computer implementation of this procedure and some of the results that have been obtained from the computer program. A user's guide to the program (called CONVOL) is given in Appendix A and FORTRAN listings are given in Appendix B.

I. THEORY

The details of the theory are presented in Ref. 2. The difference-frequency pressure at the field point (r,θ,ϕ) is given by

$$P(r,\theta,\phi) = \frac{\beta(P_0R_0k)^2}{4\pi\rho c^2} \int_0^{\pi} d\theta' \sin\theta' \int_0^{2\pi} d\phi' D_0^2(\theta', \phi') \, I\,(\cos\nu), \qquad (1)$$

where

$$\cos\nu \equiv \cos\theta' \cos\theta + \sin\theta' \sin\theta \cos(\phi' - \phi), \qquad (2)$$

$$I = \exp(-jkr) \int_0^{\infty} dy \exp(-y)\, U(\xi)(z^2 + B^2)^{-1/2}, \qquad (3)$$

$$z \equiv y - 2\alpha r \cos\nu + j2kr \sin^2(\nu/2), \qquad (4)$$

$$B^2 \equiv (1 + jk/\alpha)(2\alpha r \sin\nu)^2, \qquad (5)$$

and $U(\xi)$ is the saturation taper function,[3,4]

$$U(\xi) = (2\xi^{-2})\left[(1 + \xi)(1 + 2\xi)^{-1/2} - 1\right]. \qquad (6)$$

In Eq. (6),

$$\xi \equiv 3(\chi/\pi)^2 \eta^2 \qquad (7)$$

where

$$\chi \equiv 2\pi\beta P_0R_0f_0/\rho c^3 \qquad (8)$$

$$\eta \equiv \ln\left\{\left[1 + (N - 1)(r'/R_0) + (r'/R_0)^2\right]^{1/2} + (r'/R_0) + \frac{1}{2}(N - 1)\right\} - \ln\left\{\frac{1}{2}(N + 1)\right\}, \qquad (9)$$

$$r' = r\cos\nu + (2\alpha)^{-1}(1 + jk/\alpha)^{-1} \times \left[(1 + jk/2\alpha)z - (jk/2\alpha)(z^2 + B^2)^{1/2}\right] , \qquad (10)$$

and N is the aspect ratio of a rectangular projector (N = 1 for square or circular shapes). The quantities I, z, B^2, U, ξ, η, and r' are all complex, because the integral of Eq. (3) is the result of a transformation in the complex plane[5] of a highly oscillatory integrand. Thus the method substitutes the complications of complex arithmetic for the slow convergence inherent in the use of the oscillatory function. For example, at high amplitudes, the singularity introduced at $\xi = -1/2$ must be dealt with. (There is no pole at $\xi = 0$, since $U(0) = 1$.)

Equation (1) is a generalized form of the convolution integral used by Blue[6] and by Berktay and Leahy[7] for the farfield of absorption-limited parametric sources. The integrand involves the product of an endfire beam pattern, I (cosν), and the square of the primary beam pattern, $D_0(\theta', \phi')$. No aperture factor[8] results from the theory, because the primary beam is assumed to be spherically spreading from the projector face. Therefore the program makes beam pattern plots with and without a multiplicative aperture factor.

In the farfield, Eqs. (3) and (10) can be simplified as follows:

$$I \xrightarrow[r \to \infty]{} \frac{\exp(-jkr)}{2\alpha r + j2kr\sin^2(\nu/2)} \int_0^\infty dy \exp(-y)\, U(\xi), \qquad (11)$$

where

$$r' \xrightarrow[r \to \infty]{} y/2\alpha \left[1 + (jk/\alpha)\sin^2(\nu/2)\right] , \qquad (12)$$

and these expressions are used in the farfield option of the program.

Since the computation of the endfire pattern, I(cosν), is a lengthy one and since I is a smooth function, 225 values are first computed and stored in a table for values of ν ranging from 10^{-4} rad to 3.14 rad. In the subsequent integrations over ϕ' and θ', linear interpolation is used to evaluate I(cosν) between the tabular values. (For $\nu < 10^{-4}$ rad and $\nu > 3.14$ rad, the endpoint values are used.) The tabular values are computed with an adaptive Simpson quadrature routine,[9,10] in which the step size for the integration variable, y, is determined by the degree of success at local convergence. The integrations over the azimuthal angle, ϕ', and the polar angle, θ', are each performed by 48-point Gaussian quadrature over a number of subintervals depending on the beamwidths of the endfire and primary patterns and on the observer's polar angle, θ - Typical running times to generate a beam pattern for a square, circular or endfire projector range from about 1 minute for easy cases (absorption-limited sources with large αR_0, i.e., sources of the Westervelt[11] type) to about 5 minutes for difficult cases (saturation-limited sources with small αR_0). These times are approximately doubled for a rectangular projector, in which case beam patterns are generated in each of two planes.

II. EXPERIMENTS

The results of experiments with two different parametric sources are reported in Sec. III. The first was rectangular in shape, with active face dimensions of 0.53 m (horizontal) x 0.44 m (vertical), a mean primary frequency of 24 kHz, and a source level of 233.5 dB//1μPa-m at each primary component. The difference frequency was 2.5 kHz. Beam pattern measurements were made in the horizontal plane at a depth of 49 m in a fresh water lake (Seneca Lake, NY) in March, 1979. The range was 42.8 m and the water temperature was approximately 1°C. The Rayleigh length, R_0, was 4.0 m, $\overline{\alpha}R_0 \approx 0.001$dB, and 20 log $\chi \approx -19$dB. This source generated much of the secondary signal in the primary farfield, since the absorption parameter, αR_0, was small.

The second projector was circular, with an active face diameter of 0.91 m, a mean primary frequency of 65 kHz, and a source level of 244.5 dB//1μPa-m at each primary component. The beam pattern measurement was made at NUSC's Millstone Quarry facility in January, 1975 at a difference-frequency of 3.5 kHz. The measurement range was 82.6 m, and the depth was 15 m, where the water temperature was approximately 15°C and the salinity 3.0%. This source was saturation-limited ($\chi \approx 1.0$) in the primary nearfield, i.e., substantial generation of the difference frequency took place within the Rayleigh length, R_0 of 28.4 m. The amount of primary absorption in the nearfield, $\overline{\alpha}R_0$, was 0.51 dB.

III. RESULTS AND CONCLUSIONS

Figure 1 shows the beam pattern of the rectangular source. The circles are the experimental data, and they may be seen to lie fairly well on the computed pattern (indicated by the solid curve). Also shown (as a dashed curve) in the figure is the computed farfield pattern. For the actual observation of such a pattern, measurement ranges in excess of 5000 m would be required.[1] It may be seen that considerable change in the beam is to be expected between the measurement range of 42.8 m and the farfield, with the 3 dB beamwidth decreasing from 6° to 4.5°. The farfield pattern is shown at the correct relative amplitude, i.e., about 14 dB more source level is to be expected in the farfield, and the skirts of the pattern will grow about 4 dB in level. The ripples on the skirts of the farfield pattern are related to the square of the primary pattern, characteristic of sources with small αR_0.[4] The amplitude of the ripples is somewhat exaggerated by the assumption that both primary frequencies have identical beam patterns, whereas, in fact, the outer sidelobes will not coincide, resulting in smoother skirts than depicted here.

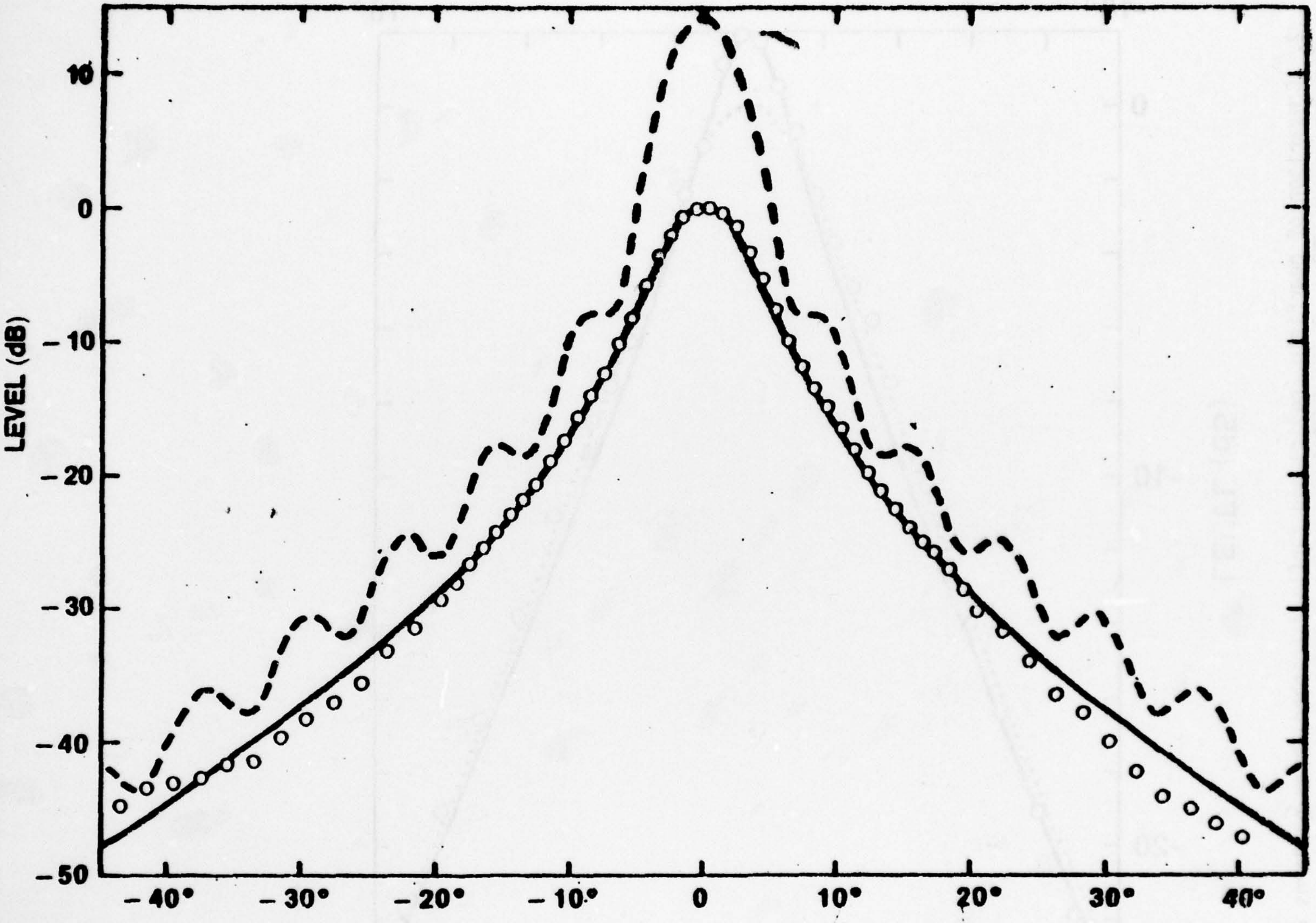
The results with the circular projector in salt water are shown in Figure 2. Again, the data are shown as circles, while the solid curve is the computed nearfield pattern and the dashed curve is the computed farfield pattern. In this case of moderately high αR_0, the nearfield source level is 2dB higher than that which would obtain in the farfield and the nearfield beamwidth is narrower than its farfield value (2.5° and 4°, respectively). The skirts of the patterns coincide, however, because the farfield conditions are reached much more quickly on the skirts than on the maximum response axis. Ranges in excess of 700 m would be required to observe the farfield pattern in this case.

The fact that nearfield beam patterns can be narrower than their farfield counterparts for parametric sources with large αR_0 has been recognized for some time,[12,13] but only more recently has it come to light that the apparent source level can be larger than the farfield value.[1,14] It is now obvious from our computer studies that the source level and beamwidth effects are tied together. For cases of large αR_0, the nearfield pattern is narrower and of higher apparent source level than the farfield pattern. For small αR_0, the nearfield pattern is broader and of lower source level than in the farfield.

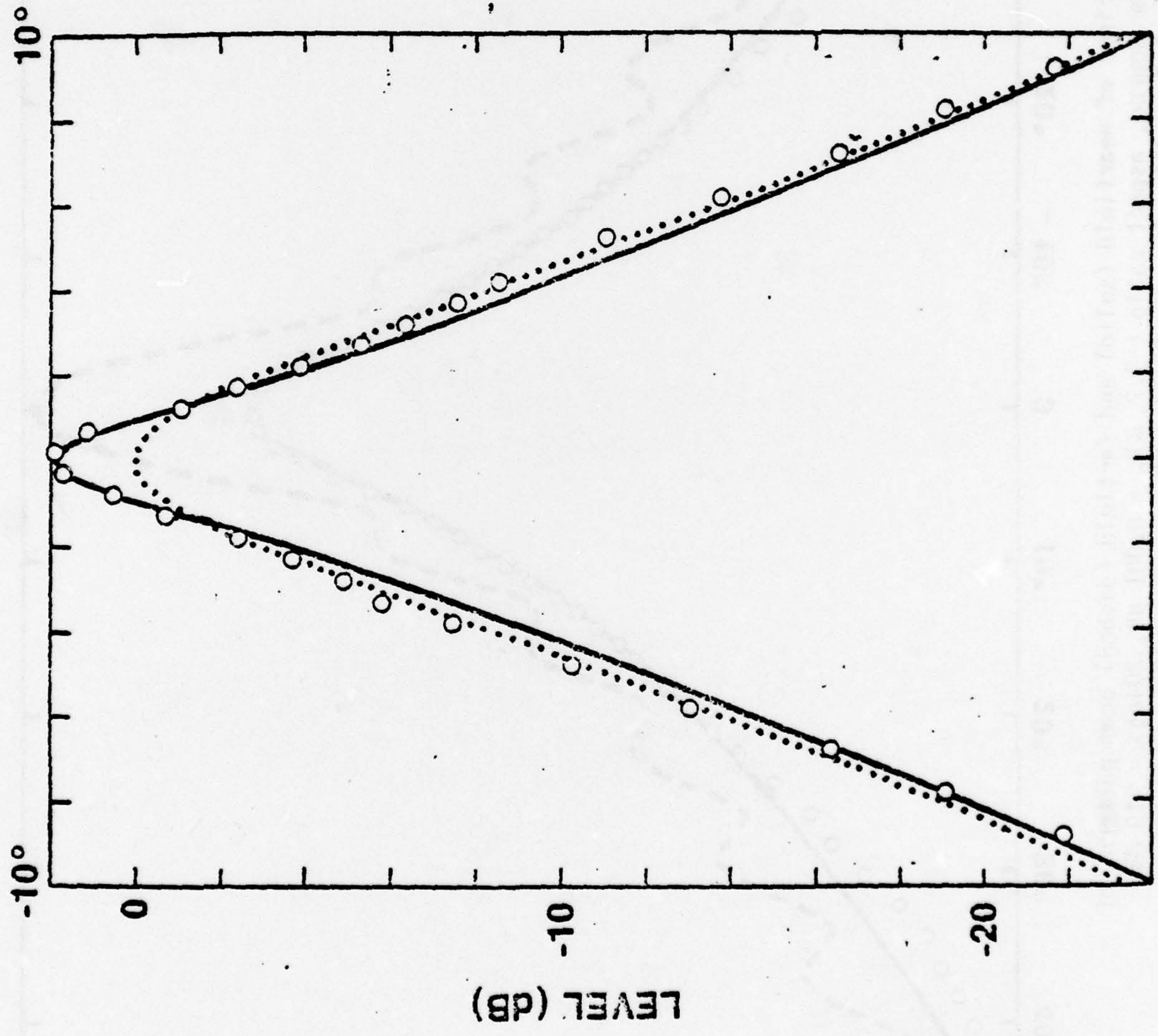
In Refs. 3 and 4, a simple, closed-form expression was suggested for beam pattern estimation. Figure 3 provides a comparison between that simplified model, shown dashed, and the present theory, shown as the solid curve, for the farfield of the 65 kHz projector. It may be seen that the simple formula predicts a 3 dB beamwidth (5.5°) which is too broad (computed value = 4°) but provides a reasonable fit to the skirts of the pattern. As discussed in Ref. 3, some error near the 3 dB points is to be expected in the use of the simple formula, because the formula was constructed from knowledge of the large-angle behavior. The present theory is to be preferred for all but rough estimates of the beam behavior.

ACKNOWLEDGEMENTS

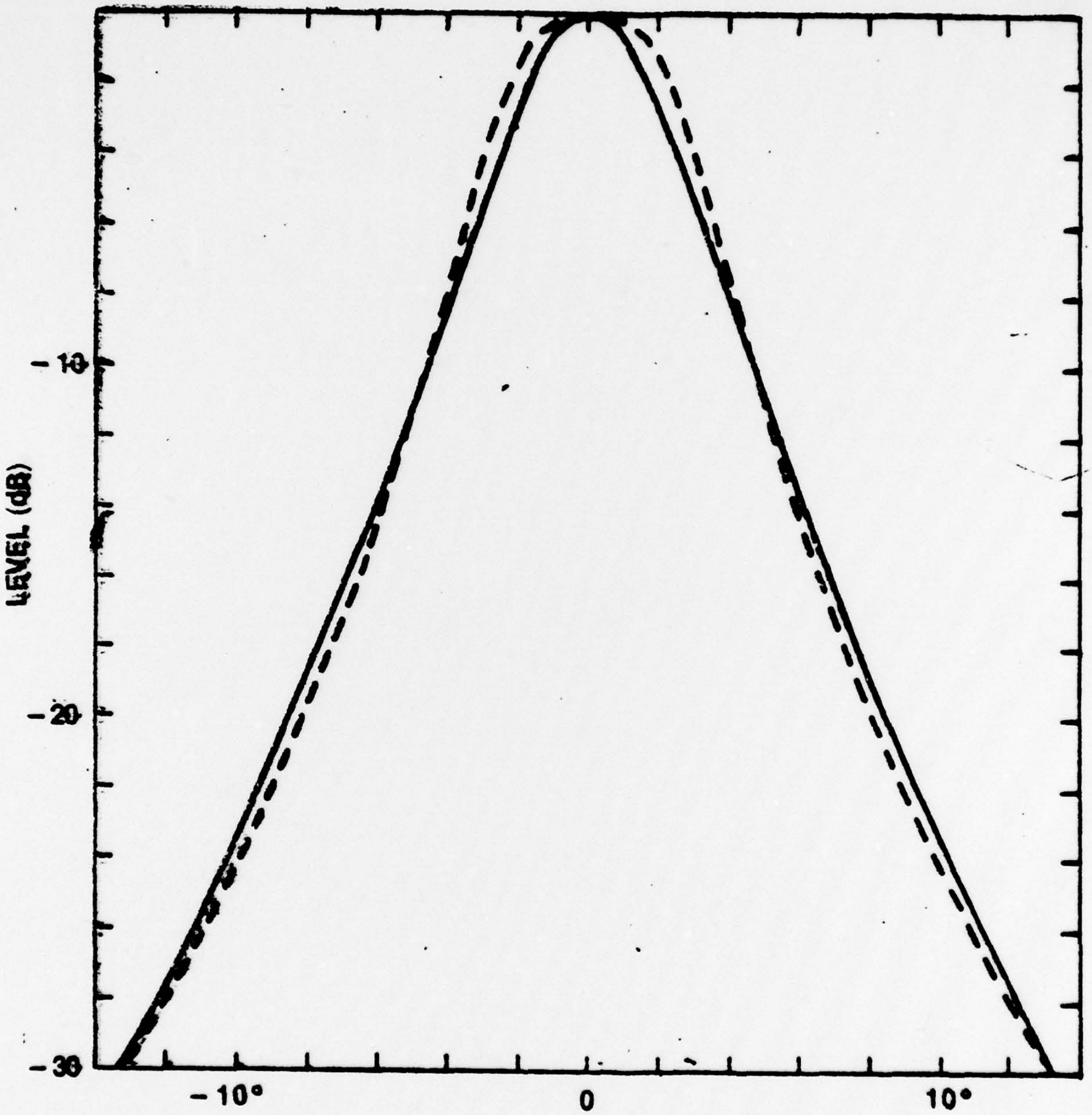
The authors would like to acknowledge the assistance of Marvin Goldstein, who provided the adaptive-Simpson's rule program and Peter Miner, who programmed the plotting routine. Experimental data were provided by William Konrad and Lynn Carlton. Assistance during various phases of the programming was obtained from George Botseas, David Potter, Joseph Auwood, Thomas Wheeler and Edmund J. Sullivan. The project was supported by the Naval Material Command.



1. Comparison of nearfield (solid) and farfield (dashed) beam patterns of rectangular source, aspect ratio = 1.2, $\overline{\alpha}R_0$ = 0.001 dB, 20logχ = -19 dB, f_0/f = 9.6, k_0R_0 = 430. For nearfield pattern, r/R_0 = 10.7. Circles: experimental nearfield data



2. Comparison of nearfield (solid) and farfield (dashed) beam patterns of circular source, $\overline{\alpha}R_0$ = 0.51 dB, 20log x = 0 dB, f_0/f = 18.6, k_0R_0 = 7740. For nearfield pattern, r/R_0 = 2.91. Circles: experimental nearfield data.



3. Comparison of present farfield theory (solid) with closed-form beam pattern expression (dashed) of Refs. 3,4. $20\log\chi = 0$ dB, $\overline{\alpha}R_0 = 0.51$ dB, $f_0/f = 18.6$, $k_0R_0 = 7740$.

APPENDIX A. CONVOL USER'S GUIDE

The CONVOL program computes parametric source beam patterns out to 45° for plane piston projectors of circular, square, and rectangular shape and for endfire line projectors. The program generates a table and plots the negative of the bearing deviation loss, denoted BDG, as well as aperture-corrected values, BDGAP, as a function of the polar observation angle, θ, with respect to the maximum response axis. For a rectangular projector, plots are generated for each of the two prinicpal observation planes at $\phi = 0$ and $\phi = 90°$, where ϕ is the azimuthal observation angle. In addition to the beam patterns, the program computes the on-axis apparent parametric gain, $20\log(rP/R_0P_0)$, i.e., the difference between the apparent secondary source level and that of one primary component. Since the apparent parametric gain can be regarded as a complex quantity,[4] its phase is also computed and the result tabulated as a function of θ.

The user must specify the projector shape through the integer parameter ISHAPE:

ISHAPE = 0: circle
1: square
2: rectangle
3: endfire. (A1)

The parameter ISHAPE is also used to indicate the end of the input data file. A negative value of ISHAPE causes the plot tape to be properly terminated so that plots can be generated off line. The other input parameters are:[4]

$$20\log X = SL_0^* - SL_1, \tag{A2}$$

i.e., the difference between the "scaled"primary source level,[15]

$$SL_0^* \equiv SL_0 + 20\log f_0 \text{ (kHz)}$$

and the value, SL_1^*, which corresponds to shock formation at Ro ($SL_1^* \approx$ 281 dB//1 μPa-m-kHz for sea water[15]),

$$\alpha R_0 (\text{dB}),$$

the amount of primary absorption loss at R_0,

$$f_0/f,$$

the "downshift" ratio of the primary and secondary frequencies,

$$k_0R_0 = \frac{1}{2} \times 10^{(DI_0/10)},$$

where DI_0 is the primary directivity index,

$$r/R_0,$$

the ratio of the observation range to R_0, and finally,[3]

N,

the aspect ratio (required only if the projector is rectangular).

The Rayleigh length, R_0, is defined as the projector face area divided by the primary wavelength for the plane piston projectors and as the projector length divided by π for endfire projectors. The program has been tested for $20\log \chi \leq 10$ dB, $\bar{\alpha}R_0 \geq 0.001$ dB, and $-100 < r/R_0 < +100$.

Typical runstream examples are given in Figures A1-A11 for operation of CONVOL on NUSC's Univac 1108 computer from a Tektronix graphics terminal. The first input data card specifies the projector type according to the value of ISHAPE in an I5 format. ISHAPE = 1(square) in the first example and 2(rectangle) in the second. The second data card provides the source parameters, $20\log\chi$ (dB), $\bar{\alpha}R_0$ (dB), f_0/f, k_0R_0, and r/R_0 in five 15-character fields. (The negative value of r/R_0 in the second example specifies infinite range.) The decimal points may be placed anywhere within their respective fields. If the projector is rectangular, as in the second example another card is needed to specify the aspect ratio, N, in the first 15-character field.

Each example is concluded with a negative value of ISHAPE to generate the plotting tape. Actually, both examples could have been run together in this case, i.e., the tabulation from the first example could have been followed with ISHAPE = 2, for the next example. If there is any doubt about whether there is sufficient time to complete all examples of a run, however, it is safer to terminate each example with a negative ISHAPE.

In each of these examples, plots were displayed first on the terminal CRT with the @ XQT D.TEKTRONIX instruction. They were then transmitted for later printing to a 1 inch = 10 dB, 1 inch = 10 deg scale with the @ XQT D.FR80 instruction. Note that these instructions were preceeded with

```
@USE D.,DISSPLA*DISSPLA.
```

```
@QUAL MOFFETT
READY
>@ASG,A $CONVOL.
READY
>@ASG,A DISSPLA*DISSPLA.
FACILITY WARNING  @002036000000
>@XQT $CONVOL.ABS
>    1
 ISHAPE=  1
>-40.            1.             10.             1000.        20.
 20LOG CHI=-40.0 DB  ALFAR0=   .1030+01 DB  DOWNSHIFT= 10.00  ROK0=
000+04  R RO=   .2000+02
 BWEF=  7.778 DEG  BWO=  4.020 DEG
 NTHETA=    1
 ON-AXIS, APPARENT PARAMETRIC GAIN = -74.6 DB

 THETA(DEG)  BDG(DB)  BDGAP(DB)  PHASE(DEG)  NPHI
     .0           .0        .0     -22.8      57
     .2          -.0       -.0     -22.9      57
     .4          -.1       -.1     -23.2      57
     .6          -.1       -.1     -23.5      57
     .8          -.2       -.2     -24.0      57
    1.0          -.3       -.4     -24.7      58
    1.2          -.5       -.5     -25.4      58
    1.4          -.7       -.7     -26.3      58
    1.6          -.9       -.9     -27.4      58
    1.8         -1.1      -1.1     -28.5      58
    2.0         -1.3      -1.3     -29.8      58
    3.0         -2.7      -2.8     -37.3      59
    4.0         -4.4      -4.5     -45.7      59
    5.0         -6.2      -6.4     -53.2      60
    6.0         -8.1      -8.4     -59.2      60
    7.0        -10.0     -10.4     -63.8      61
    8.0        -11.8     -12.3     -67.7      60
    9.0        -13.5     -14.0     -70.7      59
   10.0        -15.0     -15.7     -73.0      57
   11.0        -16.5     -17.4     -74.7      57
   12.0        -17.9     -18.9     -76.0      57
   13.0        -19.2     -20.4     -77.2      56
   14.0        -20.3     -21.7     -78.3      58
   15.0        -21.5     -23.0     -79.0      55
   16.0        -22.6     -24.4     -79.4      56
   17.0        -23.6     -25.6     -79.8      55
   18.0        -24.5     -26.8     -80.5      55
   19.0        -25.3     -27.9     -81.0      55
   20.0        -26.2     -29.0     -81.2      55
   21.0        -27.1     -30.2     -81.2      55
   22.0        -27.8     -31.3     -81.4      55
   23.0        -28.5     -32.3     -81.9      54
   24.0        -29.2     -33.4     -82.2      55
   25.0        -29.9     -34.4     -82.3      55
   26.0        -30.6     -35.5     -82.2      55
   27.0        -31.2     -36.6     -82.1      55
   28.0        -31.8     -37.6     -82.4      54
   29.0        -32.4     -38.6     -82.7      55
   30.0        -32.9     -39.6     -82.9      55
   31.0        -33.5     -40.7     -82.8      54
   32.0        -34.0     -41.8     -82.6      55
   33.0        -34.5     -42.8     -82.7      54
   34.0        -35.0     -43.9     -82.9      55
   35.0        -35.5     -44.9     -82.9      55
   36.0        -36.0     -46.1     -83.0      54
   37.0        -36.4     -47.2     -82.9      55
   38.0        -36.8     -48.4     -82.8      55
```

```
   39.0        -37.2     -49.6     -83.0      55
   40.0        -37.6     -50.8     -83.1      55
   41.0        -38.0     -52.1     -83.0      56
   42.0        -38.4     -53.6     -82.9      55
   43.0        -38.8     -54.9     -82.8      55
   44.0        -39.2     -56.4     -82.8      56
   45.0        -39.5     -58.0     -83.2      58
 BEGIN OF DISSPLA PLOT GENERATION.
>    -1

      .1
 END DISSPLA --      4229 VECTORS GENERATED IN      2 PLOT FRAMES.
>@USE D.,DISSPLA*DISSPLA.
READY
>@XQT D.TEKTRONIX



 .............. DISSPLA INTERMEDIATE PLOT FILE POSTPROCESSOR .......
.....
 ENTER SPECIAL REQUESTS OR PRESS -RETURN-
>
```

Figure A-1

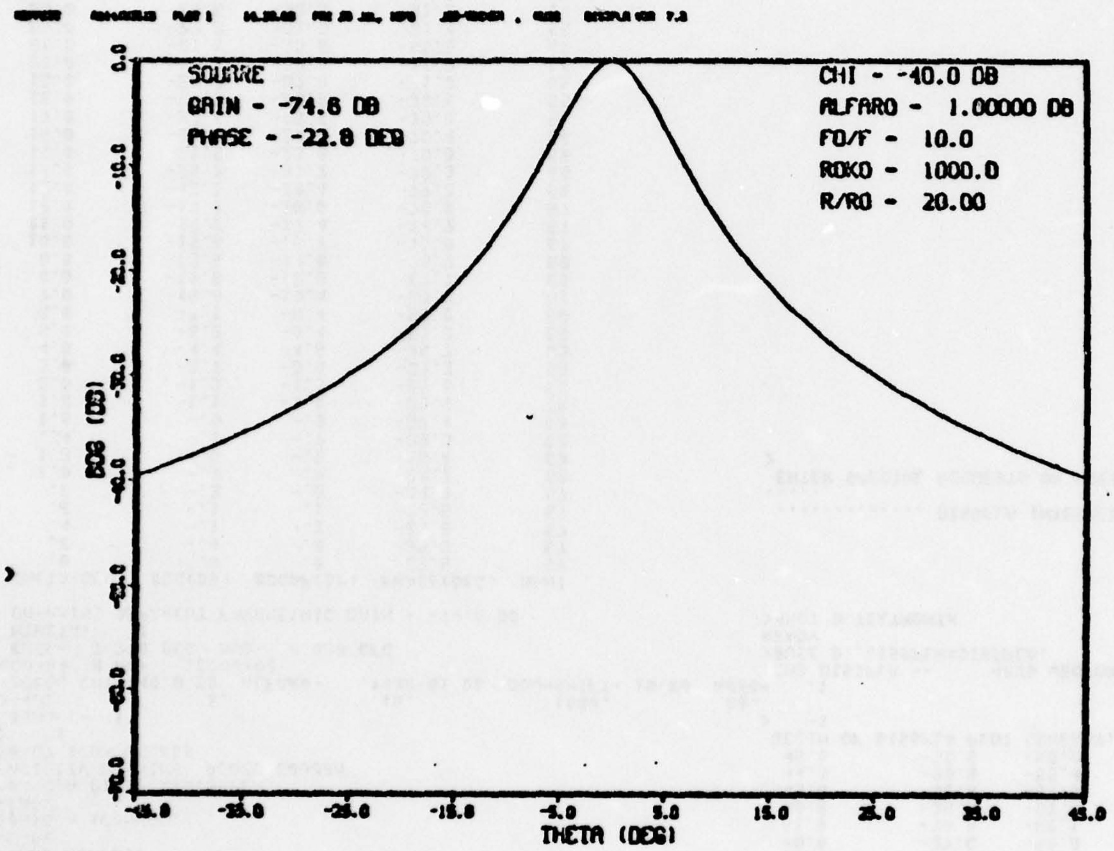

SOURCE
GAIN - -74.6 DB
PHASE - -22.8 DEG
CHI - -40.0 DB
ALFARO - 1.00000 DB
FO/F - 10.0
ROKO - 1000.0
R/RO - 20.00
EDB (DB)
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
-70.0
THETA (DEG)
-45.0
-35.0
-25.0
-15.0
-5.0
5.0
15.0
25.0
35.0
45.0

Figure A-2

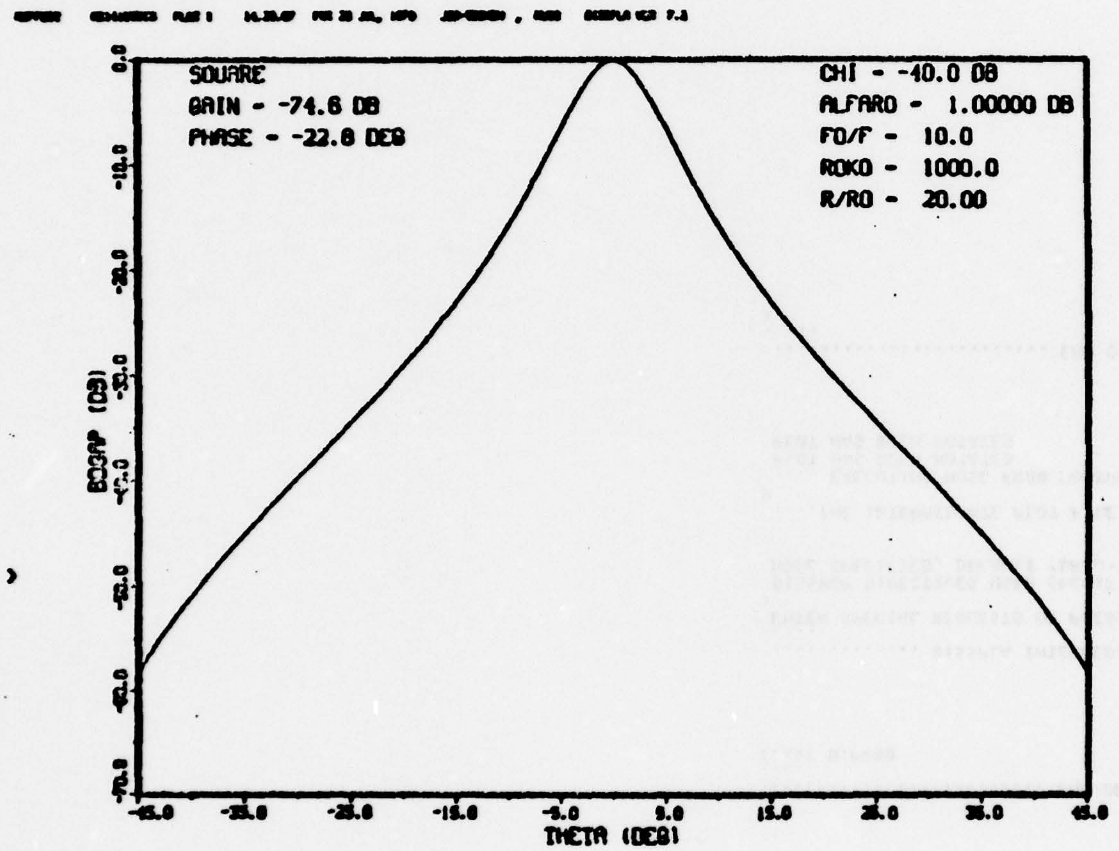
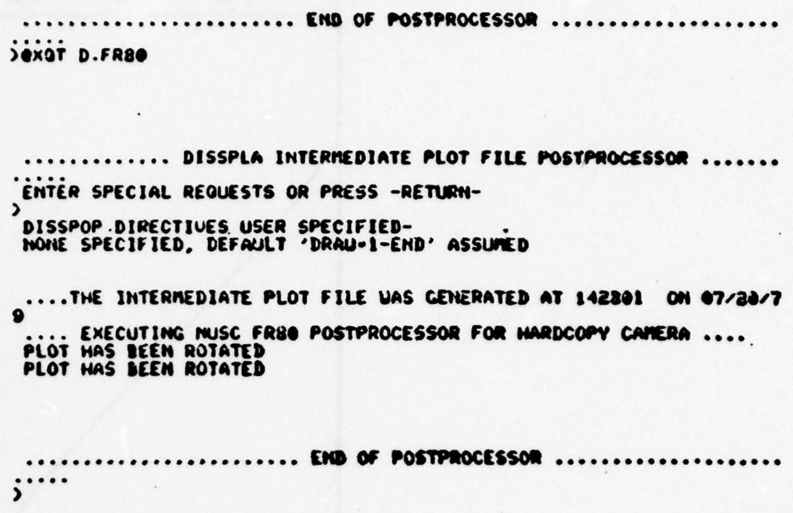

SQUARE
GAIN - -74.6 DB
PHASE - -22.8 DEG
CHI - -40.0 DB
ALFARO - 1.00000 DB
FO/F - 10.0
ROKO - 1000.0
R/RO - 20.00
BCOAP (DB)
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
-70.0
-45.0
-35.0
-25.0
-15.0
-5.0
5.0
15.0
25.0
35.0
45.0
THETA (DEG)

Figure A-3



```
........................ END OF POSTPROCESSOR ....................
.....
)@XQT D.FR80


............. DISSPLA INTERMEDIATE PLOT FILE POSTPROCESSOR .......
.....
ENTER SPECIAL REQUESTS OR PRESS -RETURN-
)
DISSPOP DIRECTIVES USER SPECIFIED-
NONE SPECIFIED, DEFAULT 'DRAW-1-END' ASSUMED

....THE INTERMEDIATE PLOT FILE WAS GENERATED AT 142801  ON 07/20/7
9
.... EXECUTING NUSC FR80 POSTPROCESSOR FOR HARDCOPY CAMERA ....
PLOT HAS BEEN ROTATED
PLOT HAS BEEN ROTATED


........................ END OF POSTPROCESSOR ....................
.....
)
```

Figure A-4

```
@XQT *CONVOL.ABS
:   2
 ISHAPE=  2
>-40.              1.              10.              1000.              -1. BEGIN OF DISSPLA PLOT GENERATION.
 20LOG CHI=-40.0 DB  ALFARO=    .1030+01 DB  DOWNSHIFT= 10.00  RCXS-ON-AXIS, APPARENT PARAMETRIC GAIN = -77.0 DB
680+04  R RO=  -.1000+01
:5.
 ASPECT=    5.0000
 BUEF=  7.778 DEG  BUO=  1.797 DEG
 NTHETA=     1
 ON-AXIS, APPARENT PARAMETRIC GAIN = -77.0 DB

 THETA(DEG)  BDG(DB)  BDGAP(DB)  PHASE(DEG)  NPHI
     .0          .0        .0       -23.8      57
     .2        -.0       -.0       -23.8      57
     .4        -.0       -.0       -23.8      57
     .6        -.1       -.1       -23.9      57
     .8        -.1       -.1       -24.1      57
    1.0        -.1       -.1       -24.3      58
    1.2        -.2       -.2       -24.5      58
    1.4        -.3       -.3       -24.8      58
    1.6        -.4       -.4       -25.1      58
    1.8        -.5       -.5       -25.4      58
    2.0        -.6       -.6       -25.8      58
    3.0       -1.3      -1.3       -28.5      59
    4.0       -2.3      -2.3       -32.2      59
    5.0       -3.5      -3.6       -37.0      60
    6.0       -4.8      -4.9       -42.8      60
    7.0       -6.3      -6.3       -49.3      61
    8.0       -7.8      -7.8       -55.9      60
    9.0       -9.2      -9.4       -63.0      59
   10.0      -10.8     -10.9       -66.9      57
   11.0      -12.3     -12.5       -70.2      57
   12.0      -13.9     -14.1       -71.8      57
   13.0      -15.4     -15.6       -71.8      56
   14.0      -16.7     -17.0       -70.9      56
   15.0      -18.0     -18.3       -69.9      55
   16.0      -19.0     -19.3       -69.7      56
   17.0      -19.9     -20.3       -70.6      55
   18.0      -20.7     -21.1       -72.3      55
   19.0      -21.4     -21.9       -74.4      55
   20.0      -22.1     -22.7       -76.5      55
   21.0      -23.0     -23.6       -77.6      55
   22.0      -23.8     -24.5       -77.8      55
   23.0      -24.7     -25.4       -77.1      54
   24.0      -25.6     -26.3       -75.5      55
   25.0      -26.4     -27.2       -73.7      55
   26.0      -27.0     -27.9       -73.5      55
   27.0      -27.6     -28.6       -72.3      56
   28.0      -28.1     -29.2       -73.0      54
   29.0      -28.6     -29.7       -74.6      55
   30.0      -29.0     -30.2       -76.8      55
   31.0      -29.6     -30.7       -78.6      54
   32.0      -30.0     -31.3       -79.5      55
   33.0      -30.5     -31.8       -79.8      54
   34.0      -31.1     -32.6       -79.0      55
   35.0      -31.7     -33.2       -77.1      56
   36.0      -32.2     -33.9       -74.9      54
   37.0      -32.7     -34.4       -73.1      55
   38.0      -33.2     -35.0       -71.8      55
   39.0      -33.6     -35.5       -71.4      56
   40.0      -33.9     -35.9       -72.1      56
   41.0      -34.2     -36.3       -74.1      56
   42.0      -34.6     -36.7       -76.3      55
```

```
   43.0      -34.9     -37.1       -78.3      55
   44.0      -35.2     -37.6       -80.3      56
   45.0      -35.5     -37.9       -81.4      56

 THETA(DEG)  BDG(DB)  BDGAP(DB)  PHASE(DEG)  NPHI
     .0          .0        .0       -23.7      57
     .2        -.0       -.0       -23.8      57
     .4        -.0       -.0       -24.1      57
     .6        -.0       -.1       -24.6      57
     .8        -.1       -.1       -25.3      57
    1.0        -.1       -.2       -26.2      58
    1.2        -.2       -.2       -27.3      58
    1.4        -.3       -.3       -28.5      58
    1.6        -.4       -.5       -29.9      58
    1.8        -.5       -.6       -31.4      58
    2.0        -.6       -.8       -33.0      58
    3.0       -1.6      -1.9       -42.6      59
    4.0       -3.1      -3.7       -52.5      59
    5.0       -5.0      -5.9       -60.9      60
    6.0       -7.0      -8.3       -67.2      60
    7.0       -8.9     -10.7       -71.8      61
    8.0      -10.8     -13.1       -75.2      60
    9.0      -12.4     -15.4       -77.8      59
   10.0      -14.0     -17.8       -79.9      57
   11.0      -15.5     -20.1       -81.6      57
   12.0      -16.8     -22.5       -82.9      57
   13.0      -18.1     -24.9       -84.0      56
   14.0      -19.3     -27.5       -84.8      56
   15.0      -20.4     -30.1       -85.5      55
   16.0      -21.6     -33.1       -85.9      56
   17.0      -22.5     -36.4       -86.2      55
   18.0      -23.4     -40.3       -86.4      55
   19.0      -24.3     -45.4       -86.4      55
   20.0      -25.1     -53.9       -86.3      55
   21.0      -25.9     -65.2       -86.1      55
   22.0      -26.6     -52.1       -85.9      55
   23.0      -27.3     -48.1       -85.7      54
   24.0      -28.0     -46.1       -85.5      55
   25.0      -28.7     -45.0       -85.5      55
   26.0      -29.3     -44.6       -85.6      55
   27.0      -29.9     -44.8       -85.8      55
   28.0      -30.5     -44.2       -86.1      54
   29.0      -31.0     -44.4       -86.6      55
   30.0      -31.6     -44.8       -87.0      55
   31.0      -32.1     -45.4       -87.4      54
   32.0      -32.6     -46.1       -87.8      55
   33.0      -33.1     -46.9       -88.0      54
   34.0      -33.6     -47.8       -88.1      55
   35.0      -34.1     -48.9       -88.1      55
   36.0      -34.6     -50.1       -87.9      54
   37.0      -35.1     -51.4       -87.6      55
   38.0      -35.5     -52.9       -87.3      55
   39.0      -35.9     -54.6       -87.0      55
   40.0      -36.3     -56.5       -86.7      55
   41.0      -36.6     -58.8       -86.4      56
   42.0      -37.0     -61.7       -86.1      55
   43.0      -37.4     -65.5       -85.9      56
   44.0      -37.7     -71.4       -85.8      56
   45.0      -38.0     -89.6       -85.7      56
>    -1
```

Figure A-5

```
@XQT D.TEKTRONIX


 ............... DISSPLA INTERMEDIATE PLOT FILE POSTPROCESSOR .............
 ENTER SPECIAL REQUESTS OR PRESS -RETURN-
>
```

Figure A-6

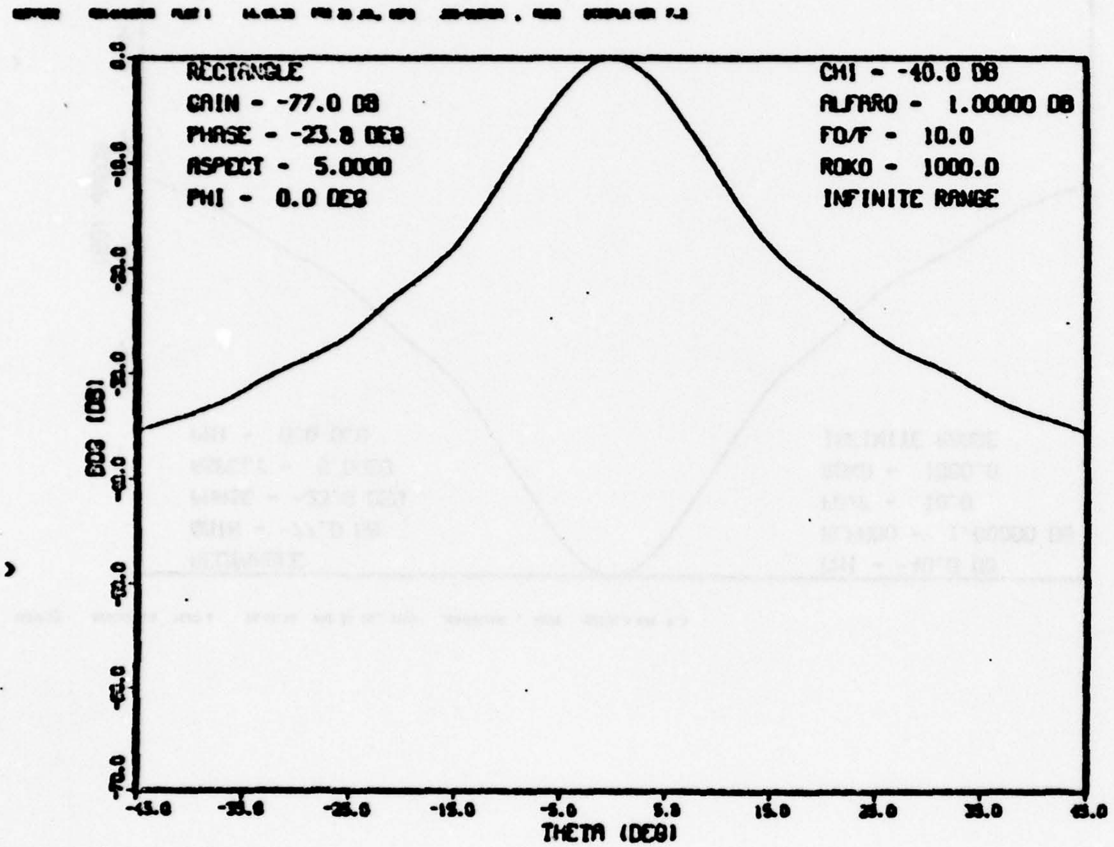

RECTANGLE
GAIN - -77.0 DB
PHASE - -23.8 DEG
ASPECT - 5.0000
PHI - 0.0 DEG
CHI - -40.0 DB
ALFARO - 1.00000 DB
FO/F - 10.0
ROKO - 1000.0
INFINITE RANGE
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
-70.0
EDG (DB)
-45.0
-35.0
-25.0
-15.0
-5.0
5.0
15.0
25.0
35.0
45.0
THETA (DEG)

Figure A-7

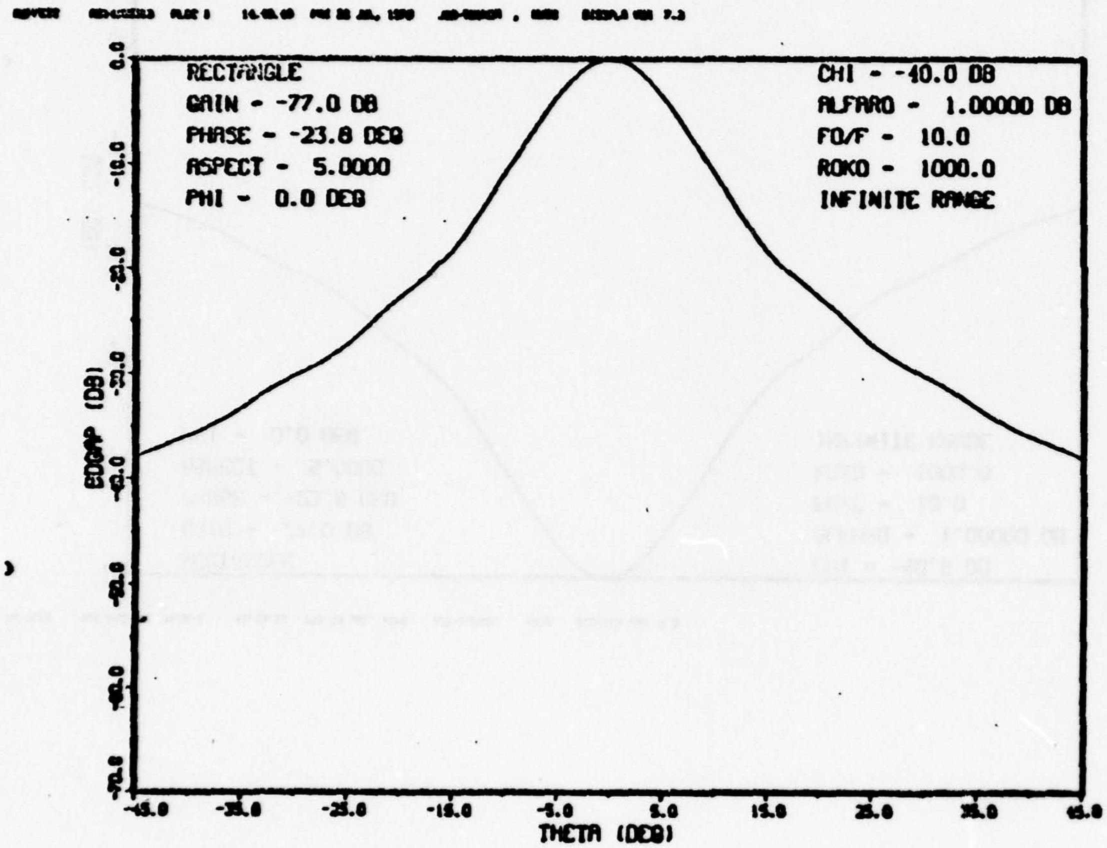

RECTANGLE
GAIN - -77.0 DB
PHASE - -23.8 DEG
ASPECT - 5.0000
PHI - 0.0 DEG
CHI - -40.0 DB
ALFARO - 1.00000 DB
FO/F - 10.0
ROKO - 1000.0
INFINITE RANGE
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
-70.0
EDGAP (DB)
-45.0
-35.0
-25.0
-15.0
-5.0
5.0
15.0
25.0
35.0
45.0
THETA (DEG)

Figure A-8

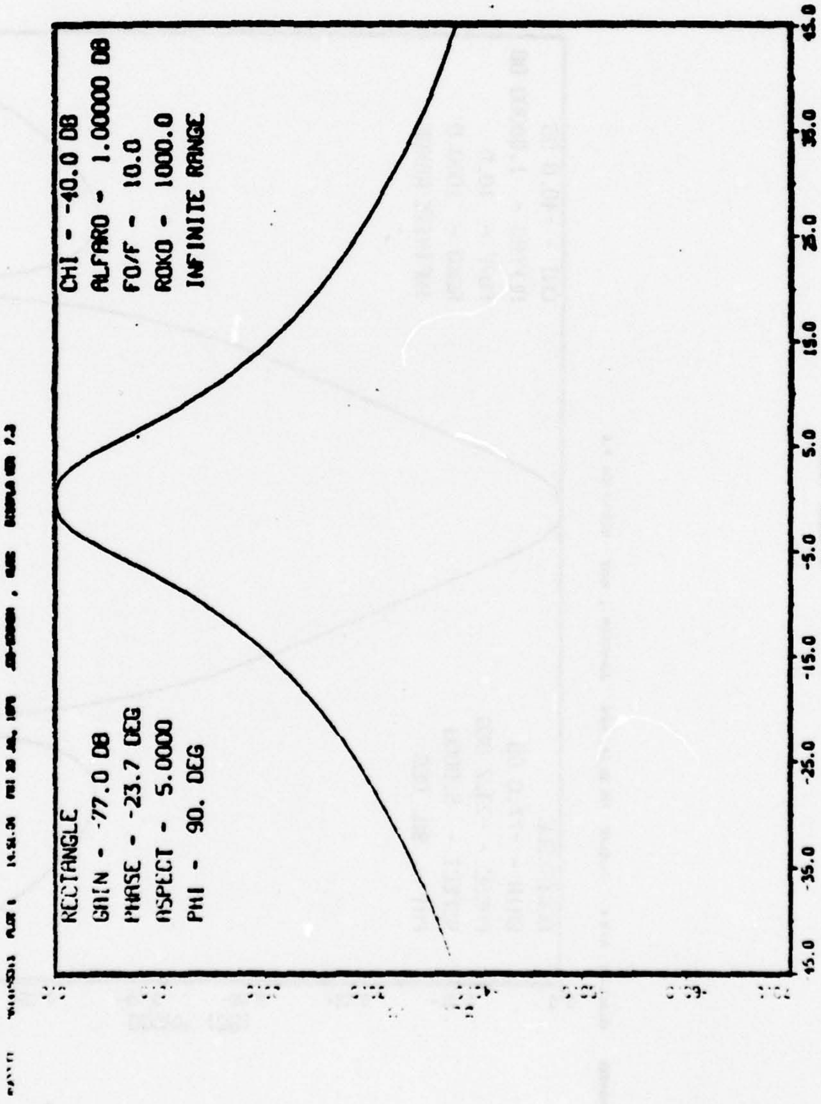

RECTANGLE
GAIN - -77.0 DB
PHASE - -23.7 DEG
ASPECT - 5.0000
PHI - 90. DEG
CHI - -40.0 DB
ALFARO - 1.00000 DB
FO/F - 10.0
ROKO - 1000.0
INFINITE RANGE
-45.0
-35.0
-25.0
-15.0
-5.0
5.0
15.0
25.0
35.0
45.0
THETA (DEG)

Figure A-9

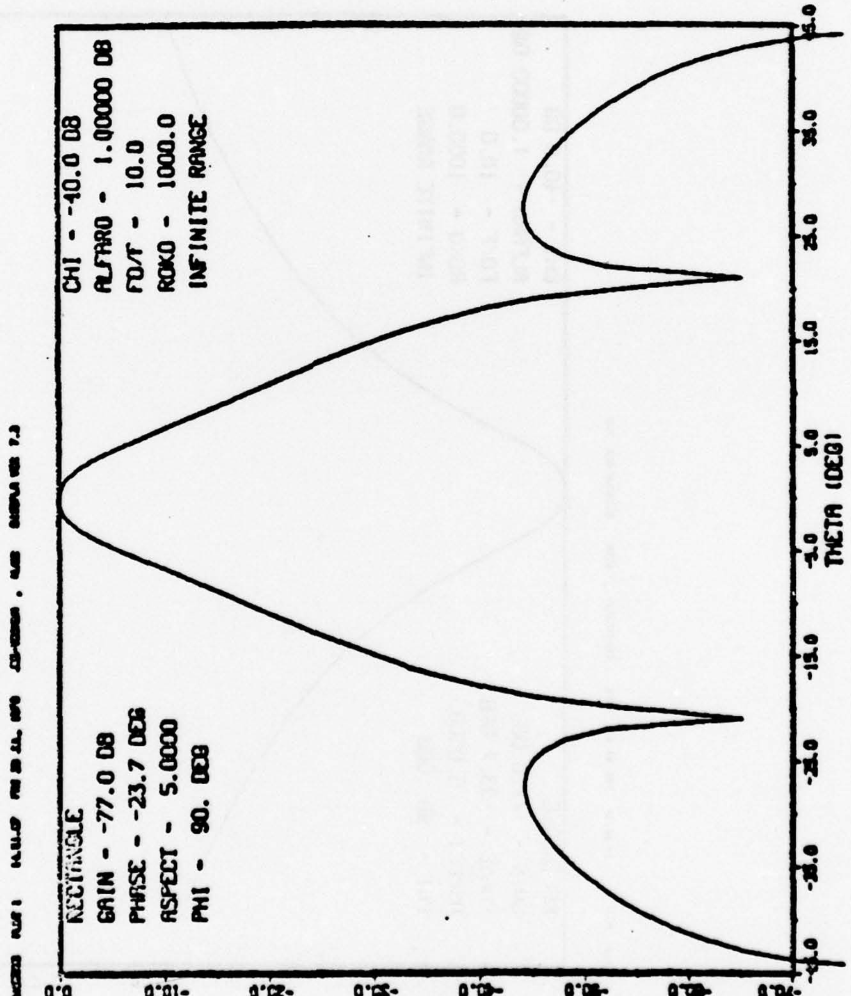

RECTANGLE
GAIN - -77.0 DB
PHASE - -23.7 DEG
ASPECT - 5.0000
PHI - 90. DEG
CHI - -40.0 DB
ALFARO - 1.00000 DB
FO/T - 10.0
ROKO - 1000.0
INFINITE RANGE
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
-70.0
EDGAP (DB)
-45.0
-35.0
-25.0
-15.0
-5.0
5.0
15.0
25.0
35.0
45.0
THETA (DEG)

Figure A-10

```
........................ END OF POSTPROCESSOR ....................
.....
>@XQT D.FR80



............. DISSPLA INTERMEDIATE PLOT FILE POSTPROCESSOR .......
.....
 ENTER SPECIAL REQUESTS OR PRESS -RETURN-
>
 DISSPOP DIRECTIVES USER SPECIFIED-
 NONE SPECIFIED, DEFAULT 'DRAW-1-END' ASSUMED

 ....THE INTERMEDIATE PLOT FILE WAS GENERATED AT 144833  ON 07/20/7
9
 .... EXECUTING MUSC FR80 POSTPROCESSOR FOR HARDCOPY CAMERA ....
 PLOT HAS BEEN ROTATED
 PLOT HAS BEEN ROTATED
 PLOT HAS BEEN ROTATED
 PLOT HAS BEEN ROTATED



 ........................ END OF POSTPROCESSOR ....................
.....
>
```

Figure A-11

APPENDIX B. CONVOL FORTRAN LISTING

The various elements of CONVOL are listed on the following pages. The main program calls subroutine QGM48, which generates coefficients for the Gaussian quadrature, and subroutine TABLE, which stores the real and imaginary values of exp(jkr) I(cosν) in arrays VALUE1 and VALUE2, respectively. TABLE does this by calling function ADPSBC, the adaptive Simpson's routine. ADPSBC requires integrand evalutations from the function FNC, which in turn, calls UEVAL for the evaluation of U, the saturation taper function. When TABLE has completed its job, the main program performs the integration over θ', using the coefficients generated by QGM48. The θ' integrand evaluations and integrations over ϕ' are done by subroutine FCTPHI, which evaluates the ϕ' integrand by interpolation of the table stored in VALUE1 and VALUE2. The beam pattern data is stored by subroutine MMSTOR and plotting instructions are generated by MMPLOT.

IN 44 DATE

```
 N
 0-08:21:14-(0,)
 C     THIS PROGRAM COMPUTES THE NEARFIELD PARAMETRIC GAIN RP/ROPO AS A
 C     FUNCTION OF OBSERVATION ANGLE THETA.  MAX RUN TIME = 20 MIN.
 C     (R0=PROJECTOR AREA/PRIMARY WAVELENGTH FOR CIRCULAR,SQUARE, AND
 C     RECTANGULAR PROJECTORS.  R0=PROJECTOR LENGTH/PI FOR ENDFIRE CASE.)
 C         INPUTS     ISHAPE=0 CIRCLE
 C                           1 SQUARE
 C                           2 RECTANGLE
 C                           3 ENDFIRE
 C                        .LT.0 STOP
 C                    CHIDB=20LOG10(CHI)(DB)       MAX=10 DB
 C                    ALFARO=ALPHA*R0(DB)          MIN=0.001 DB
 C                    DOWNSR=F0/F                  MIN=2.0
 C                    ROKO=K0*R0                   MIN=1.4
 C                    RANGE=R/R0 (IF RANGE.LT.0, FARFIELD GAIN COMPUTED)
 C                            -100 .LE. RANGE .LE. 100  (NE. ZERO)
 C                    ASPECT (IFF ISHAPE=2)        MIN=1.0
 C         OUTPUTS    RK=KR
 C                    CONST3=3*(CHI/PI)**2
 C                    TWOALF=2*ALPHA*R
 C                    PI=3.14159265
 C                    PHIR=PHI(RAD)
 C                    CTH=COS(THETA)
 C                    STH=SIN(THETA)
 C                    THETA(DEG)
 C                    BDG(DB)=BEARING DEVIATION GAIN
 C                    BDGAP(DB)=BDG+20LOG(APERTURE FACTOR)
 C                    GAIN(DB)
 C                    PHASE(DEG)
 C                    FASE(DEG)=AXIAL VALUE OF PHASE
 C                    NAPFAC=0 NO APERTURE FACTOR
 C                           1 APERTURE FACTOR INCLUDED
 C                    BWEFR(RAD)=WESTERVELT BEAMWIDTH
 C                    BWOR(RAD)=PRIMARY BEAMWIDTH
 C                    NTHETA=NO. OF THETAPRIME POINTS / 48
 C                    NPHI=NO.OF PHIPRIME POINTS / 48
       DIMENSION IC(2)
       COMMON/ELK/U0,V0,TWOALF,RK
       COMMON/TAN/RANGE
       COMMON/BLUE/ASPECT,ISHAPE
       COMMON/YELLOW/CONST3
       COMMON/PURPLE/ NPOINT
       COMMON/ODRAB/ CHIDB,ALFARO,DOWNSR,GAIN,FASE,NAPFAC
       COMMON/WHT/C(24),W(24)
       COMMON/GREY/BWEFR,BWOR,ICOUNT,STH,CTH,PI
       COMMON/PINK/ROKO,PHIR
       CALL COMPRS
       CALL FIRST
       ICCK='00800.'
       PI=3.14159265
       E=EXP(1.0)
       DEGRAD=PI/180.
       CALL QGM48
  1000 READ (5,10) ISHAPE
    10 FORMAT(I5)
       IF(ISHAPE.LT.0) GO TO 900
```

```
      PRINT 10 ISHAPE
   10 FORMAT(1X,'ISHAPE=',I3)
      READ (3,11) CHIDB,ALFARO,DOWNSR,ROKO,RANGE
   11 FORMAT(5E15.6)
      PRINT 12 CHIDB,ALFARO,DOWNSR,ROKO,RANGE
   12 FORMAT(1X,'20LOG CHI=',F5.1,1X,'DB',2X,'ALFARO=',E11.4,1X,'DB',2X
     *,'DOWNSHIFT=',F5.2,2X,'ROKO=',E11.4,2X,'R/R0=',E11.4)
      IF(ISHAPE.EQ.2) GO TO 1003
      ASPECT=1.0
      GO TO 1004
 1003 READ (3,17) ASPECT
   17 FORMAT(E15.6)
      PRINT 18 ASPECT
   18 FORMAT(1X,'ASPECT=',F10.4)
 1004 IF(ISHAPE.GT.3) GO TO 1007
      IF(ALFARO.LE.0.0) GO TO 1007
      IF(DOWNSR.LE.0.0) GO TO 1007
      IF(ROKO.LT.1.4) GO TO 1007
      IF(RANGE.EQ.0.0) GO TO 1007
      IF(ASPECT.LT.1.0) GO TO 1007
      BWEFR=4.0*ASIN(SQRT(ALFARO*DOWNSR/(20.*DLOG10(E)*ROKO)))
      BWEF=BWEFR/DEGRAD
      IF(ISHAPE.EQ.0) BWOR=2.0*ASIN(SQRT(1.31/ROKO))
      IF(ISHAPE.EQ.1) BWOR=2.0*ASIN(SQRT(1.25/ROKO))
      IF(ISHAPE.EQ.2) BWOR=2.0*ASIN(SQRT(1.25/(ROKO*ASPECT)))
      IF(ISHAPE.EQ.3) BWOR=4.0*ASIN(SQRT(0.442/ROKO))
      BWO=BWOR/DEGRAD
      PRINT 27 BWEF,BWO
   27 FORMAT(1X,'BWEF=',F7.3,' DEG',2X,'BWO=',F7.3,' DEG')
      NTHETA=1+INT(1.0/BWO)
      ENN=FLOAT(NTHETA)
      PRINT 26 NTHETA
   26 FORMAT(1X,'NTHETA=',I5)
      CHI=10.**(0.05*CHIDB)
      RK=ROKO*RANGE/DOWNSR
      CONST3=3.0*(CHI/PI)**2
      TWOALF=0.1*ALFARO*RANGE/ALOG10(E)
      COEFF=CHI*RANGE*ROKO/(4.0*PI*DOWNSR*DOWNSR)
      CALL TAPLE
      PHIR=0.0
      GO TO 1006
 1005 PHIR=PI*0.5
C     START OF POINT GENERATION
 1006 NPOINT=0
      DO 1041 N=1,54
      IF(N.LE.10) THETA=FLOAT(N-1)*.2
      IF(N.GT.10) THETA=FLOAT(N-9)
      THETAR=THETA*DEGRAD
      CTH=COS(THETAR)
      STH=SIN(THETAR)
      ANS1=0.0
      ANS2=0.0
      ANS3=0.0
      ANS4=0.0
      KPHI=0
      IF(BWEF.GT.BWO) GO TO 1030
      IF(THETA.LT.0.5*BWEF) GO TO 1031
      IF(THETA.LT.90.-0.5*BWEF) GO TO 1032
      GO TO 1033
C  INTEGRAL FROM 0 TO PI/2:
 1030 B=0.5*PI/ENN
      BHALF=0.5*B
      A=0.5*PI-BHALF
      DO 1022 J=1,NTHETA
      CALL PROC01
      A=A-B
 1022 CONTINUE
      ANS1=ANS3*B
      ANS2=ANS4*B
      GO TO 1034
C  INTEGRAL FROM BWEFR TO PI/2:
 1031 B=(0.5*PI-BWEFR)/ENN
      BHALF=0.5*B
      A=0.5*PI-BHALF
      DO 1027 J=1,NTHETA
      CALL PROC01
      A=A-B
 1027 CONTINUE
      ANS1=ANS3*B
      ANS2=ANS4*B
C  INTEGRAL FROM 0 TO BWEFR:
      ANS3=0.0
      ANS4=0.0
      B=BWEFR
      BHALF=0.5*B
      A=BHALF
      CALL PROC01
      ANS3=ANS3*B
      ANS4=ANS4*B
C  ACCUMULATION FOR TOTAL INTEGRAL:
      ANS1=ANS1+ANS3
      ANS2=ANS2+ANS4
      GO TO 1034
 1032 K=(NTHETA+1)/2
      L=NTHETA-K
      IF(L.EQ.0) L=1
      DKAY=FLOAT(K)
      DELL=FLOAT(L)
C  INTEGRAL FROM (THETAR+BWEFR/2) TO PI/2:
      B=(0.5*(PI-BWEFR)-THETAR)/DELL
      BHALF=0.5*B
      A=0.5*PI-BHALF
      DO 1035 J=1,L
      CALL PROC01
      A=A-B
 1035 CONTINUE
      ANS1=ANS3*B
      ANS2=ANS4*B
C  INTEGRAL FROM 0 TO (THETAR-BWEFR/2):
      ANS3=0.0
      ANS4=0.0
      B=(THETAR-0.5*BWEFR)/DKAY
      BHALF=0.5*B
      A=THETAR-0.5*BWEFR-BHALF
      DO 1037 J=1,K
      CALL PROC01
      A=A-B
 1037 CONTINUE
      ANS3=ANS3*B
      ANS4=ANS4*B
C  ACCUMULATION:
      ANS1=ANS1+ANS3
      ANS2=ANS2+ANS4
C  INTEGRAL FROM (THETAR-BWEFR/2) TO (THETAR+BWEFR/2):
      ANS3=0.0
      ANS4=0.0
      B=BWEFR
      BHALF=0.5*B
      A=THETAR
      CALL PROC01
      ANS3=ANS3*B
      ANS4=ANS4*B
C  ACCUMULATION FOR TOTAL INTEGRAL:
      ANS1=ANS1+ANS3
      ANS2=ANS2+ANS4
      GO TO 1034
C  INTEGRAL FROM 0 TO (PI/2-BWEFR):
 1033 B=(0.5*PI-BWEFR)/ENN
      BHALF=0.5*B
      A=0.5*PI-BWEFR-BHALF
      DO 1040 J=1,NTHETA
      CALL PROC01
      A=A-B
 1040 CONTINUE
      ANS1=ANS3*B
      ANS2=ANS4*B
C  INTEGRAL FROM (PI/2-BWEFR) TO.PI/2:
      ANS3=0.0
      ANS4=0.0
      B=BWEFR
      BHALF=0.5*B
      A=0.5*PI-BHALF
      CALL PROC01
      ANS3=ANS3*B
      ANS4=ANS4*B
C  ACCUMULATION FOR TOTAL INTEGRAL:
      ANS1=ANS1+ANS3
      ANS2=ANS2+ANS4
 1034 PHASE=ATAN2(ANS2,ANS1)
      PHASE=PHASE/DEGRAD
      IF(N.GT.1) GO TO 1020
      RGAIN=10.*ALOG10(ANS1*ANS1+ANS2*ANS2)
      FASE=PHASE
      GAIN=RGAIN+10.*ALOG10(COEFF*COEFF)
      PRINT 19 GAIN
   19 FORMAT(1X,'ON-AXIS, APPARENT PARAMETRIC GAIN =',F6.1,1X,'DB')
      PRINT 13
   13 FORMAT(1H0,'THETA(DEG)',2X,'BDG(DB)',2X,'BDGAP(DB)',2X,'PHASE(DEG)
     *',2X,'NPHI')
 1020 BDG=10.*ALOG10(ANS1*ANS1+ANS2*ANS2)-RGAIN
      IF(N.EQ.1) GO TO 1017
```

IN 44 DATE

```
      IF(ISHAPE.EQ.0.OR.ISHAPE.EQ.3) GO TO 1014
      ARG11=SQRT(0.5*ROKO*PI)*STH/DOWNSR
      IF(ISHAPE.EQ.1) GO TO 1015
      RTAS=SQRT(ASPECT)
      IF(PHIR.EQ.0.0) GO TO 1016
      ARG11=ARG11*RTAS
      GO TO 1015
 1016 ARG11=ARG11/RTAS
 1015 DAP=SIN(ARG11)/ARG11
      GO TO 1013
 1014 ARG11=SQRT(2.0*ROKO)*STH/DOWNSR
      DAP=2.0*BSSL(ARG11,3)/ARG11
      ARG11=0.5*PI*ROKO*(1.0-CTH)/DOWNSR
      IF(N.LE.11) ARG11=0.25*PI*ROKO*(THETAR**2)/DOWNSR
      IF(ISHAPE.EQ.3) DAP=SIN(ARG11)/ARG11
 1013 DAPSQ=DAP**2
      IF(DAPSQ.EQ.0.0) DAPSQ=1.0E-08
      BDGAP=BDG+10.*ALOG10(DAPSQ)
      GO TO 1019
 1017 BDGAP=0.0
 1019 PRINT 14 THETA,BDG,BDGAP,PHASE,NPHI
   14 FORMAT(1X,F5.1,7X,F6.1,3X,F6.1,5X,F6.1,6X,I4)
      CALL MMSTOR(THETA,BDG,BDGAP)
 1041 CONTINUE
      NAPFAC=0
      CALL MMPLOT
      NAPFAC=1
      CALL MMPLOT
      IF(PHIR.EQ.0.0) GO TO 1002
      GO TO 1021
 1002 IF(ISHAPE.EQ.2) GO TO 1005
 1021 CALL SECOND(IC)
C     DON'T START ANY BEAM PATTERNS AFTER 900 SEC HAS ELAPSED.
      IF(IC(1).GE.ICCK) GO TO 900
      GO TO 1001
  900 CALL DONEPL
      STOP DONE
 1007 PRINT 21
   21 FORMAT(1X,'BAD INPUT.  NEXT CASE.')
      GO TO 1001
C   PROCEDURE PROC01
      SUBROUTINE PROC01
      DO 1023 I=1,24
      CALL FCT(A+BHALF*C(I),ARG1,ARG2)
      NPHI=NPHI+ICOUNT
      ARG3=ARG1
      ARG4=ARG2
      CALL FCT(A-BHALF*C(I),ARG1,ARG2)
      NPHI=NPHI+ICOUNT
      ANS3=ANS3+W(I)*(ARG3+ARG1)*0.5
 1023 ANS4=ANS4+W(I)*(ARG4+ARG2)*0.5
      RETURN
      END
```

```
BIN 44

BLE
23-08:53:48-(0,)
        SUBROUTINE TABLE
 C     THIS SUBPROGRAM TABULATES EXP(JKR)*I(COSNU) FOR 0.0001.LE.GNU.LE.
 C     3.14, WITH REAL PARTS STORED IN VALUE1(N) AND IMAGINARY PARTS
 C     STORED IN VALUE2(N).  THE INDEX N IS RELATED TO GNU BY
 C     GNU = FLOAT(N)/10000        1.LE.N.LE. 10
 C             FLOAT(N-9)/1000    10.LE.N.LE. 19
 C             FLOAT(N-18)/100    19.LE.N.LE.118
 C             FLOAT(N-68)/50    118.LE.N.LE.225
 C     COSNU IS NEGATIVE FOR GNU.GT.PI/2.
 C         INPUTS      TWOALF=2*ALPHA*R
 C                     RK=KR
 C                     RANGE=R/R0
 C         OUTPUTS     U0=TWOALF*COSNU
 C                     V0=KR*(1-COSNU)
 C                     CONST1=COSNU*R/R0
 C                     VALUE1(225)
 C                     VALUE2(225)
 C                     AKOTAL=ALPHA/(2*K)
 C                     BSQ=B**2      (COMPLEX)
       EXTERNAL FNC
       COMPLEX BSQ
       COMMON/BLK/U0,V0,TWOALF,RK
       COMMON/TAN/RANGE
       COMMON/RED/VALUE1(240),VALUE2(240)
       COMMON/BROWN/CONST1,AKOTAL
       COMMON/GRN/X(23),V(23)
       COMMON/FUCIA/BSQ
       YMAX=20.
       EPSI=0.5E-02
       DO 201 N=1,225
       IF(N-10) 203,203,204
   203 GNU=FLOAT(N)*1.0E-04
       GO TO 205
   204 IF(N-19) 208,208,209
   208 GNU=FLOAT(N-9)*1.0E-03
       GO TO 205
   209 IF(N-118) 212,212,213
   212 GNU=FLOAT(N-18)*0.01
       GO TO 205
   213 GNU=FLOAT(N-68)*0.02
   205 COSNU=COS(GNU)
       U0=TWOALF*COSNU
       V0=RK*(1.0-COSNU)
       IF(N.LT.19) V0=RK*((GNU**6)/720.-(GNU**4)/24.+0.5*(GNU**2))
       CONST1=COSNU*RANGE
       AKOTAL=RK/TWOALF
       BSQ=CMPLX(1.0,2.0*AKOTAL)*(TWOALF**2)*((SIN(GNU))**2)
       A=0.0
       B=YMAX
       E=EPSI
       VALUE1(N)=ADPSBC(A,B,FNC,1,E,NP1)
       A=0.0
       B=YMAX
       E=EPSI
       VALUE2(N)=ADPSBC(A,B,FNC,2,E,NP2)
```

```
      IF(RANGE.GT.0.0) GO TO 201
      VEE=V0/TWOALF
      DEN=-1./(TWOALF*(1.+VEE**2))
      V1=VALUE1(N)
      V2=VALUE2(N)
      VALUE1(N)=(V1+VEE*V2)*DEN
      VALUE2(N)=(V2-VEE*V1)*DEN
  201 CONTINUE
      RETURN
      END
```

```
) BIN 44

ADPSBC
7/23-08:54:07-(0,)
       FUNCTION ADPSBC(A,B,FNC,INDEX,EPS,NP)
C***********PROGRAMMED BY M. J. GOLDSTEIN***********
C*************************************************************
C*****THIS SINGLE PRECISION SUBPROGRAM APPROXIMATES THE*****
C*****INTEGRAL FROM A TO B OF THE FUNCTION FNC(X,INDEX)*****
C*****TO WITHIN A RELATIVE ERROR EPS BY ADAPTIVE SIMPSON****
C*****QUADRATURE AND RETURNS THE APPROXIMATION IN ADPSBC.***
C*****THE FUNCTION FNC(X,INDEX) IS A SINGLE PRECISION ******
C*****EXTERNAL FUNCTION SUBPROGRAM WHICH EVALUATES THE *****
C*****FUNCTION AT POINT X. INDEX IS A POINTER TO ONE OF ****
C*****SEVERAL INTEGRANDS CONTAINED IN THE CODE OF     ******
C*****FNC(X,INDEX). NP IS RETURNED TO THE CALLING PRO- *****
C*****GRAM AS ONE LESS THAN THE NUMBER OF INTEGRAND EVAL- **
C*****UATIONS USED TO OBTAIN THE RESULT ADPSBC.        *****
C*******************************************************
       DIMENSION EPSP(30),F2(30),F3(30),FMP(30),XM(30),FBP(30),DX(30),
      *X2(30),X3(30),EST2(30),ITRN(30),PVAL(30,2)
       LOGICAL TEST
       CORR = 0.0
       NP = 0
       EPS = 15.0*EPS
       LVL = 0
       ABSA = 1.0
       EST = 1.0
       DA = B - A
       FA = FNC(A,INDEX)
       FM = 4.0*FNC((A + B)*0.5,INDEX)
       FB = FNC(B,INDEX)
       NP = 2
       ASSIGN 20001 TO PROC01
       GO TO 30001
 20001 CONTINUE
 20002 CONTINUE
       IF(.NOT.(TEST)) GO TO 20003
       LVL = LVL - 1
       ICOL = ITRN(LVL)
       PVAL(LVL,ICOL) = SUM
       ASSIGN 20005 TO PROC02
       GO TO 30002
 20005 CONTINUE
       GO TO 20004
 20003 CONTINUE
       ITRN(LVL) = 1
       DA = DX(LVL)
       FM = F2(LVL)
       FB = FMP(LVL)
       EPS = EPSP(LVL)*0.5
       EST = EST1    $ SAVE 3 POINT APPROX. ON (A, A+DA)
       ASSIGN 20006 TO PROC01
       GO TO 30001
 20006 CONTINUE
 20004 CONTINUE
       IF(.NOT.(LVL.EQ.1)) GO TO 20002
       ADPSBC = SUM - CORR/15.0
       RETURN
```

```
C
C
C
C
C      PROCEDURE RECUR
30001 CONTINUE
      LVL = LVL + 1
      DX(LVL) = DA*0.5
      SX = DX(LVL)/6.0
      XM(LVL) = A + DX(LVL)
      X2(LVL) = A+DX(LVL)*0.5
      F2(LVL) = 4.0*FNC(X2(LVL),INDEX)
      X3(LVL) = X2(LVL) + DX(LVL)
      F3(LVL) = 4.0*FNC(X3(LVL),INDEX)
      EPSP(LVL) = EPS
C TOLERANCE MUST BE .GT. 15/(2**27) TO AVOID NOISE PROBLEMS:
C IN NEXT STATEMENT, LVLMAX IS SUCH THAT
C (2**LVLMAX) .LT. (30*E07*EPSI)
      IF(LVL.GT.20) EPSP(LVL)=1.0E-07
      FMP(LVL) = FM*0.25
      EST1 = (FA + F2(LVL) + FMP(LVL))*SX
      FBP(LVL) = FB
      EST2(LVL) = (FMP(LVL) + F3(LVL) + FB)*SX
      SUM = EST1 + EST2(LVL)              @ STORE 5 POINT APPROX. IN SUM
      ABSA = ABSA - ABS(EST) + ABS(EST1) + ABS(EST2(LVL))
      CI = EST - SUM
      TEST = ABS(CI).LE.EPSP(LVL)*ABSA        .@ SET COMPARISON TEST
      TEST = TEST.AND.(EST.NE.1.0)
      TEST = TEST.OR.LVL.GE.30
      IF(TEST)CORR = CORR + CI
      NP = NP +2
      GO TO PROC01
C
C
C
C
C      PROCEDURE CAS
30002 CONTINUE
      GO TO(20007,20008), ICOL
20007 CONTINUE
      ITRN(LVL) = 2
      DA = DX(LVL)
      FA = FMP(LVL)
      FM = F3(LVL)
      FB = FBP(LVL)
      EPS = EPSP(LVL)*0.5
      A = XM(LVL)
      EST = EST2(LVL)
      ASSIGN 20010 TO PROC01
      GO TO 30001
20010 CONTINUE
      GO TO  20009
20008 CONTINUE
      SUM = PVAL(LVL,1) + PVAL(LVL,2)
20009 CONTINUE
      GO TO PROC01
      END
```

```
9IN 44

C
23-08:54:25-(0,)
      FUNCTION FNC(Y,INDEX)
 C    THIS SUBPROGRAM COMPUTES THE INTEGRAND
 C        U*EXP(-Y)/SQRT(Z**2+B**2)         IF RANGE.GT.0.
 C        U*EXP(-Y)                         IF RANGE.LT.0
 C        INPUTS     Y
 C                   INDEX=1 OR 2
 C                   U0=TWOALF*COSNU
 C                   V0=KR*(1-COSNU)
 C                   RANGE
 C                   BSQ=B**2                    (COMPLEX)
 C        OUTPUTS    RT=SQRT(Z**2+B**2)          (COMPLEX)
 C                   FNC(Y,1)=REAL PART
 C                   FNC(Y,2)=IMAGINARY PART
      COMPLEX RT,Z,U,Y3,BSQ
      COMMON/BLK/U0,VC,TWOALF,RK
      COMMON/TAN/RANGE
      COMMON/ORANGE/RT
      COMMON/FUCIA/BSQ
      IF(RANGE.( .0.0) GO TO 401
      Z=CMPLX(Y+U0,-VC)
      RT=CSQRT(Z**2+BSQ)
      CALL UEVAL(Y,Z,U)
      Y3=U*CMPLX(EXP(-Y),0.)
      IF(INDEX.EQ.1) FNC=REAL(Y3)
      IF(INDEX.EQ.2) FNC=AIMAG(Y3)
      RETURN
  401 Z=CMPLX(Y-U0,VC)
      RT=CSQRT(Z**2+BSQ)
      CALL UEVAL(Y,Z,U)
      Y3=U*CMPLX(EXP(-Y),0.)/RT
      IF(INDEX.EQ.1) FNC=REAL(Y3)
      IF(INDEX.EQ.2) FNC=AIMAG(Y3)
      RETURN
      END
```

```
BIN 44

VAL
23-03:54:37-(0,)
      SUBROUTINE UEVAL(Y,Z,U)
C THIS SUBPROGRAM COMPUTES THE SATURATION-TAPER U(RT/RO).
C         INPUTS     Y   (USED ONLY IF RANGE.LT.ZERO)
C                    V0  (USED ONLY IF RANGE.LT.ZERO)
C                    Z                              (COMPLEX)
C                    CONST1=COSNU*RANGE
C                    CONST3=3*(CHI/PI)**2
C                    RT=SQRT(Z**2+B**2)             (COMPLEX)
C                    TWOALF=2*ALPHA*R
C                    RANGE
C                    ASPECT
C                    AKOTAL=ALPHA/(2*K)
C                    ISHAPE=0,1,2,OR 3
C                    BSQ=B**2                       (COMPLEX)
C         OUTPUT     U                              (COMPLEX)
      COMPLEX RT,Z,U,BB,RPRIME,XI,BSQ,DELTA
      COMMON/BLK/U0,V0,TWOALF,RK
      COMMON/TAN/RANGE
      COMMON/BLUE/ASPECT,ISHAPE
      COMMON/YELLOW/CONST3
      COMMON/BROWN/CONST1,AKOTAL
      COMMON/ORANGE/RT
      COMMON/FUCIA/BSQ
C IF CHIDB.LE.-35, SET U=(1.0,0.0)
      IF(CONST3.LT.1.0E-04) GO TO 101
      ZTEST=CABS(Z-RT)/CABS(Z)
      RPRIME=CMPLX(1.,AKOTAL)*Z-CMPLX(0.,AKOTAL)*RT
      IF(ZTEST.LE.0.01) RPRIME=Z*((1.,0.)-CMPLX(0.,.5*AKOTAL)*
     *((BSQ/Z**2)-(.25,0.)*((BSQ/Z**2)**2)+(.125,0.)*((BSQ/Z**2)**3)))
      RPRIME=RPRIME*CMPLX((RANGE/TWOALF),0.)/CMPLX(1.,2.*AKOTAL)
      IF(RANGE.LT.0.0) RPRIME=CMPLX(RANGE*Y,0.)/CMPLX(TWOALF,V0)
      IF(RANGE.GT.0.0) RPRIME=RPRIME+CMPLX(CONST1,0.)
      IF(ISHAPE.NE.2) BB=RPRIME+CSQRT((1.,0.)+RPRIME**2)
      IF(ISHAPE.EQ.2) BB=((2.,0.)*RPRIME+CMPLX(ASPECT-1.,0.)+(2.,0.)*
     *CSQRT((1.,0.)+CMPLX(ASPECT-1.,0.)*RPRIME+RPRIME**2))
     */CMPLX(1.+ASPECT,0.)
      XI=CMPLX(CONST3,0.)*(CLOG(BB)**2)
      IF(CABS(RPRIME).LT.0.1.AND.ISHAPE.NE.2) XI=CMPLX(CONST3,0.)*
     *((.075,0.)*(RPRIME**5)-CMPLX(1./6.,0.)*(RPRIME**3)+RPRIME)**2
      IF(ISHAPE.NE.2) GO TO 103
      DELTA=CMPLX(0.5*(ASPECT-1.0),0.0)
      IF(CABS(RPRIME).LT.0.1.AND.CABS(DELTA).LT.0.02) XI=
     *CMPLX(CONST3,0.)*(CMPLX(ALOG(2./(1.+ASPECT)),0.)+DELTA+RPRIME
     *-(.5,0.)*DELTA**2+(DELTA+RPRIME)*(DELTA**2-(2.,0.)*DELTA
     **RPRIME-RPRIME**2)/(3.,0.)-(.25,0.)*DELTA**4+(.2,0.)*(DELTA
     *+RPRIME)*(DELTA**4-RPRIME*DELTA**3+(DELTA*RPRIME)**2+(1.5,0.)
     **DELTA*RPRIME**3+(.375,0.)*RPRIME**4))**2
  103 IF(CABS(XI).LT.0.02) GO TO 102
      XITEST=CABS((1.,0.)+(2.,0.)*XI)
      IF(XITEST.LT.1.0E-18) U=((1.,0.)+XI)*(1.0E09,0.)
      IF(XITEST.GE.1.0E-18.AND.XITEST.LE.0.01) U=((1.,0.)+XI)/CSQRT
     *(CMPLX(0.01/XITEST,0.)*((1.,0.)+(2.,0.)*XI))-(1.,0.)
      IF(XITEST.GT.0.01) U=((1.,0.)+XI)/CSQRT((1.,0.)+(2.,0.)*XI)
     *-(1.,0.)
      U=U*(2.,0.)/(XI**2)
```

```
BIN 44

      RETURN
  102 U=(1.,0.)-(2.,0.)*XI+(3.75,0.)*(XI**2)-(7.,0.)*(XI**3)
      RETURN
  101 U=(1.,0.)
      RETURN
      END
```

```
 GIN 44

GM48
/23-08:55:02-(0,)
        SUBROUTINE GGM48
  C     THIS SUBPROGRAM COMPUTES WEIGHTING FACTORS FOR THE GAUSSIAN
  C     QUADRATURE.
        COMMON/WHT/C(24),W(24)
        C(1)=.99877101
        C(2)=.99353017
        C(3)=.98412458
        C(4)=.97059159
        C(5)=.95298770
        C(6)=.93138669
        C(7)=.90587914
        C(8)=.87657202
        C(9)=.84358826
        C(10)=.80706620
        C(11)=.76715903
        C(12)=.72403413
        C(13)=.67737233
        C(14)=.62886740
        C(15)=.57722473
        C(16)=.52316097
        C(17)=.46690290
        C(18)=.40868648
        C(19)=.34875589
        C(20)=.28736249
        C(21)=.22476379
        C(22)=.16122236
        C(23)=.97004699E-1
        C(24)=.32380171E-1
        W(1)=.31533461E-2
        W(2)=.73275539E-2
        W(3)=.11477235E-1
        W(4)=.15579316E-1
        W(5)=.19616160E-1
        W(6)=.23570761E-1
        W(7)=.27426510E-1
        W(8)=.31167228E-1
        W(9)=.34777223E-1
        W(10)=.38241351E-1
        W(11)=.41545083E-1
        W(12)=.44674561E-1
        W(13)=.47616658E-1
        W(14)=.50357036E-1
        W(15)=.52890189E-1
        W(16)=.55199504E-1
        W(17)=.57277292E-1
        W(18)=.59114840E-1
        W(19)=.60704439E-1
        W(20)=.62039423E-1
        W(21)=.63114192E-1
        W(22)=.63924239E-1
        W(23)=.64460164E-1
        W(24)=.64737697E-1
        RETURN
        END
```

```
T
23-08:55:16-(0,)
       SUBROUTINE FCT(ARG,ARG1,ARG2)
 C    THIS SUBPROGRAM COMPUTES THE THETAPRIME INTEGRAND =
 C         SIN(THETAPRIME)*DO**2*(INTEGRAL OVER PHIPRIME).
 C         INPUTS      STH=SIN(THETA)
 C                     CTH=COS(THETA)
 C                     ARG=THETAPRIME
 C                     PHIR=PHI(RAD)
 C                     ASPECT
 C                     ISHAPE=0,1,2,OR 3
 C                     ROKO
 C                     C(24)
 C                     W(24)
 C         OUTPUTS     ARG1=REAL PART
 C                     ARG2=IMAGINARY PART
 C                     ICOUNT=NO.OF PHIPRIME POINTS / 48
       COMMON/BLUE/ASPECT,ISHAPE
       COMMON/WHT/C(24),W(24)
       COMMON/GREY/BWEFR,BWOR,ICOUNT,STH,CTH,PI
       COMMON/PINK/ROKO,PHIR
       S=SIN(ARG)
       CO=COS(ARG)
       COCTH=CO*CTH
       SSTH=S*STH
       N=1+INT(PI*S/(180.*BWOR))
       NNNN=N
       ARG1=0.0
       ARG2=0.0
       ARG11=0.0
       ARG12=0.0
       ICOUNT=0
       IF(ISHAPE.EQ.0.OR.ISHAPE.EQ.3) GO TO 604
       IF(ISHAPE.EQ.1) GO TO 605
       ARG3=SQRT(0.5*PI*ROKO/ASPECT)*S
       IF(PHIR.EQ.0.0) GO TO 606
       ARG3=ARG3*ASPECT
       GO TO 606
   604 IF(ISHAPE.EQ.0) ARG3=SQRT(2.0*ROKO)*S
       IF(ISHAPE.EQ.3) ARG3=0.5*PI*ROKO*(1.0-CO)
       IF(ISHAPE.EQ.3.AND.S.LE.0.01) ARG3=0.25*PI*ROKO*(ARG**2)
       N=1
       GO TO 606
   605 ARG3=SQRT(PI*ROKO*0.5)*S
   606 ENN=FLOAT(N)
       IF(N.EQ.1) GO TO 622
       IF(BWEFR.GE.BWOR/S) GO TO 623
   622 IF(BWEFR.GE.1.0) GO TO 623
       IF(DABS(S-STH).LT.BWEFR) GO TO 618
   623 B=PI/ENN
       A=PI-0.5*B
       L=1
       GO TO 625
   618 B=(PI-BWEFR)/ENN
       A=PI-0.5*B
       L=2
   625 DO 626 J=1,NNNN
```

```
  619 DO 603 I=1,24
      DO 617 K=1,2
      DKAY=FLOAT(K)
      PHIPRI=A+B*C(I)*(1.5-DKAY)
      COSNU=COCTH+SSTH*COS(PHIPRI)
      CALL FCTPHI(COSNU,VAL1,VAL2)
      IF(ISHAPE.EQ.0.OR.ISHAPE.EQ.3) GO TO 607
      CPRI=COS(PHIPRI)
      SPRI=SIN(PHIPRI)
      ARG4=ARG3*CPRI
      ARG5=ARG3*SPRI
      IF(ISHAPE.EQ.1) GO TO 612
      IF(PHIR.EQ.0.0) GO TO 616
      ARG5=ARG5/ASPECT
      GO TO 612
  616 ARG5=ARG5*ASPECT
  612 IF(ARG4.EQ.0.0) GO TO 608
      DD=SIN(ARG4)/ARG4
      GO TO 609
  608 DD=1.0
  609 IF(ARG5.EQ.0.0) GO TO 610
      DD=DD*SIN(ARG5)/ARG5
  610 FAC=(DD**2)*W(I)
      GO TO 614
  607 FAC=W(I)
  614 ARG1=ARG1+FAC*VAL1
  617 ARG2=ARG2+FAC*VAL2
  603 CONTINUE
      ICOUNT=ICOUNT+1
      IF(L.EQ.3) GO TO 621
      A=A-B
  626 CONTINUE
      FAC=B*S
      IF(L.EQ.1) GO TO 625
      L=3
      ARG11=ARG1*FAC
      ARG12=ARG2*FAC
      ARG1=0.0
      ARG2=0.0
      B=BWEFR
      A=0.5*B
      NNNN=1
      GO TO 625
  621 FAC=B*S
      ARG1=ARG1*FAC+ARG11
      ARG2=ARG2*FAC+ARG12
      GO TO 629
  625 ARG1=ARG1*FAC
      ARG2=ARG2*FAC
  629 IF(ISHAPE.EQ.1.OR.ISHAPE.EQ.2) GO TO 613
      IF(ARG3.EQ.0.0) GO TO 601
      IF(ISHAPE.EQ.0) DD=2.0*BSSL(ARG3,3)/ARG3
      IF(ISHAPE.EQ.3) DD=SIN(ARG3)/ARG3
      DD=DD**2
      GO TO 602
  601 DD=1.0
  602 CONTINUE
```

```
BIN 44

TPHI
23-08:55:39-(0,)
      SUBROUTINE FCTPHI(COSNU,VAL1,VAL2)
C     THIS SUBPROGRAM COMPUTES THE PHIPRIME INTEGRAND, EXP(JKR)*I(COSNU).
C         INPUTS     COSNU
C                    VALUE1(225)
C                    VALUE2(225)
C         OUTPUTS    VAL1=REAL PART
C                    VAL2=IMAGINARY PART
      COMMON/RED/VALUE1(240),VALUE2(240)
      GNU=ACOS(COSNU)
      C=1.0E04*GNU
      I=INT(C)
      IF(I.GT.0).GO TO 500
      VAL1=VALUE1(1)
      VAL2=VALUE2(1)
      RETURN
  500 IF(I.LT.10) GO TO 502
      IF(I.GE.100) GO TO 501
      C=1000.*GNU+9.
      GO TO 506
  501 IF(I.GE.10000) GO TO 504
      C=100.*GNU+18.
      GO TO 506
  504 IF(I.GE.31400) GO TO 507
      C=50.*GNU+68.
      GO TO 506
  507 VAL1=VALUE1(225)
      VAL2=VALUE2(225)
      RETURN
  506 I=INT(C)
  502 CII=C-FLOAT(I)
      VAL1=VALUE1(I)
      VAL1=VAL1+(VALUE1(I+1)-VAL1)*(CII)
      VAL2=VALUE2(I)
      VAL2=VAL2+(VALUE2(I+1)-VAL2)*(CII)
      RETURN
      END
```

```
BIN 44

      ARG1=ARG1*DC
      ARG2=ARG2*DC
  613 RETURN
      END
```

```
SIN 44

ORPLOT
23-08:55:55-(0,)
      SUBROUTINE MMSTCR(THETA,BDG,BDGAP)
      PARAMETER MPTS=200
C     PETER R MINER   APR 1977
      COMMON/TAN/RANGE
      COMMON/BLUE/ASPECT,ISHAPE
      COMMON/PURPLE/ NPOINT,XARRAY(MPTS),YARRAY(MPTS),ZARRAY(MPTS)
      COMMON/ODRAB/ CHIDB,ALFARO,DOWNSR,GAIN,FASE,NAPFAC
      COMMON/PINK/ROKC,PHIR
      NPOINT=NPOINT+1
      IF(NPOINT.GT.MPTS) GO TO 50
      XARRAY(NPOINT)=THETA
      YARRAY(NPOINT)=BDG
      ZARRAY(NPOINT)=BDGAP
      RETURN
   50 WRITE(4,2000)
 2000 FORMAT(' PLOT STORAGE OVERFLOW')
      NPOINT=MPTS
      RETURN
C
C     PLOT CURVE
      ENTRY MMPLOT
      CALL NOBRDR
      IF(NAPFAC.EQ.0) GO TO 101
      CALL TITLE(' ',-1,'THETA (DEG)',11,'BDGAP (DB)',10,9.,7.)
      GO TO 102
  101 CALL TITLE(' ',-1,'THETA (DEG)',11,'BDG (DB)',8,9.,7.)
  102 CALL NOCHEK
      CALL FRAME
      CALL GRAF(-45.,10.,45.,-70.,10.,0.)
      CALL XTICKS(2)
      CALL YTICKS(2)
C     CALL DOT
C     CALL GRID(2,1)
C     CALL RESET('DOT')
      IF(NAPFAC.EQ.0) GO TO 103
      CALL CURVE(XARRAY,ZARRAY,NPOINT,0)
      GO TO 104
  103 CALL CURVE(XARRAY,YARRAY,NPOINT,0)
  104 DO 100 I=1,NPOINT
      XARRAY(I)=-XARRAY(I)
  100 CONTINUE
      IF(NAPFAC.EQ.0) GO TO 105
      CALL CURVE(XARRAY,ZARRAY,NPOINT,0)
      GO TO 106
  105 CALL CURVE(XARRAY,YARRAY,NPOINT,0)
C
C     PLOT VARIABLES
  106 I=ISHAPE+1
      GO TO (150,160,170,180), I
  150 CALL MESSAG('CIRCLE',6,.5,6.8)
      GO TO 200
  160 CALL MESSAG('SQUARE',6,.5,6.8)
      GO TO 200
  170 CALL MESSAG('RECTANGLE',9,.5,6.8)
      GO TO 200
  180 CALL MESSAG('ENDFIRE',7,.5,6.8)
  200 CALL MESSAG('GAIN = ',7,.5,6.5)
      AVALUE=GAIN
      CALL REALNO(AVALUE,103,'ABUT',6.5)
      CALL MESSAG(' DB',3,'ABUT',6.5)
      CALL MESSAG('PHASE = ',8,.5,6.2)
      AVALUE=FASE
      CALL REALNO(AVALUE,103,'ABUT',6.2)
      CALL MESSAG(' DEG',4,'ABUT',6.2)
      IF(ISHAPE.NE.2) GO TO 250
      CALL MESSAG('ASPECT = ',9,.5,5.9)
      AVALUE=ASPECT
      CALL REALNO(AVALUE,105,'ABUT',5.9)
      CALL MESSAG('PHI = ',6,.5,5.6)
      IF(PHIR.EQ.0.) AVALUE=0.
      IF(PHIR.NE.0.) AVALUE=90.
      CALL REALNO(AVALUE,102,'ABUT',5.6)
      CALL MESSAG(' DEG',4,'ABUT',5.6)
C
C     PLOT VARIABLES, RIGHT SIDE
  250 CALL MESSAG('CHI = ',6,6.5,6.8)
      AVALUE=CHIDB
      CALL REALNO(AVALUE,103,'ABUT',6.8)
      CALL MESSAG(' DB',3,'ABUT',6.8)
      CALL MESSAG('ALFARO = ',9,6.5,6.5)
      AVALUE=ALFARO
      CALL REALNO(AVALUE,106,'ABUT',6.5)
      CALL MESSAG(' DB',3,'ABUT',6.5)
      CALL MESSAG('FD/F = ',7,6.5,6.2)
      AVALUE=DOWNSR
      CALL REALNO(AVALUE,103,'ABUT',6.2)
      CALL MESSAG('ROKO = ',7,6.5,5.9)
      AVALUE=ROKO
      CALL REALNO(AVALUE,105,'ABUT',5.9)
      IF(RANGE.LT.0.000) GO TO 210
      CALL MESSAG('R/RO = ',7,6.5,5.6)
      AVALUE=RANGE
      CALL REALNO(AVALUE,104,'ABUT',5.6)
      GO TO 220
  210 CALL MESSAG('INFINITE RANGE',14,6.5,5.6)
  220 CALL ENDPL(-1)
      RETURN
      END
```

REFERENCES

1. R.H. Mellen, "Nearfield axial levels of exponentially shaded end-fire arrays," J. Acoust. Soc. Am. 61, 599-602 (L) (1977).

2. R.H. Mellen & M.B. Moffett, "A numerical method for calculating the nearfield of a parametric acoustic source," J. Acoust. Soc. Am. 63, 1622-1624 (L) (1978).

3. M.B. Moffett, R.H. Mellen, & W.L. Konrad, "Parametric acoustic sources of rectangular aperture," J. Acoust. Soc. Am. 63, 1326-1331 (1977).

4. M.B. Moffett & R.H. Mellen, "Model for parametric acoustic sources," J. Acoust. Soc. Am. 61, 325-337 (1977).

5. R.H. Mellen, "Nearfield beam patterns of exponentially shaded end-fire line arrays," J. Acoust. Soc. Am. 60, 505-506 (L) (1976).

6. J.E. Blue, "Nonlinear Acoustics in Undersea Communication," U.S. Navy J. Underwater Acoust. 22, 177-187 (1972) (publication of the Office of Naval Research).

7. H.O. Berktay & D.J. Leahy, " Farfield performance of parametric transmitters," J. Acoust. Soc. Am. 55, 539-546 (1974).

8. M.B. Moffett & R.H. Mellen. "On parametric source aperture factors," J. Acoust. Soc. Am. 60, 581-583 (1976).

9. J.N. Lyness, "Notes on the Adaptive Simpson Quadrature Routine," J. Assoc. Comp. Mach. 16, 483-495 (1969).

10. M.J. Goldstein, "Adaptive Simpson Quadrature," NUSC Technical Memo 771142 (12 July, 1977).

11. P.J. Westervelt, "Parametric Acoustic Array," J. Acoust. Soc. Am. 35, 535-537 (1963).

12. H.O. Berktay & J.A. Shooter, "Nearfield effects in end-fire line arrays," J. Acoust. Soc. Am. 53, 550-556 (1973).

13. M. Vestrheim & H. Hobaek, "Angular Distribution of Nonlinearly Generated Difference Frequency Sound," Proc. Symp. Nonlin. Acoust. Univ. Birmingham, 1971 (British Acoustical Society, London), pp. 137-158.

14. H. Hobaek & S. Tjøtta, "Theory of Parametric Acoustic Arrays," to be published in J. Physique.

15. H.M. Merklinger, R.H. Mellen, & M.B. Moffett, "Finite-amplitude losses in spherical sound waves, J. Acoust. Soc. Am. 59, 755-759 (1976).